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CONTENTS.

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RECORDS

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PETROLOGICAL STUDY OF SOME ROCKS FROM THE HILL TRACTS, VIZAGAPATAM DISTRICT, MADRAS PRESIDENCY. BY T. L. WALKER, M.A., PH.D., *University of Toronto,* and W. H. COLLINS, *Geological Survey of Canada.* (With Plates 1, 2, and 3.)

CONTENTS.

I.—GENERAL STATEMENT.

THE material for the study of which the results are presented in the present paper was collected by Mr. C. S. Middlemiss, Superintendent of the Geological Survey of India, during the field seasons 1901-02 and 1902-03, while conducting the geological survey of the Hill Tracts of Vizagapatam district. The suite of specimens appears to represent a metamorphic series of rocks resulting from various stages of mingling of ultra-basic igneous and of argillaceous sedimentary materials. We think that the evidence contained in this

paper justifies us in regarding these interesting rocks containing sapphirine, cordierite, spinel, sillimanite, and hypersthene as having been produced by the action of spinel iron-ore ultra-basic igneous border products on khondalite rich in sillimanite, representing the metamorphosed sedimentary mantle which frequently overlies the great igneous mass which forms the northern part of the Eastern Ghauts.

Our thanks are due to the Director of the Geological Survey of India for the opportunity of working over this very interesting suite of rocks, to Messrs. Middlemiss and Vredenburg for maps and notes regarding their field characteristics and distribution, and to Principal Galbraith, School of Practical Science, Toronto, for his assistance in the preparation of microphotographs.

The chemical analysis reported in this paper and also those parts dealing with the charnockites and with the end members of the sapphirine-bearing series are entirely the work of Mr. Collins. In addition to this he has contributed to most of the other sections of the report.

II.—SAPPHIRINE-BEARING ROCKS AND THEIR ASSOCIATES.

The present section of this paper deals with a highly interesting series of rock specimens collected during the season of 1902-03 in the district of Vizagapatam, by Mr. C. S. Middlemiss, who has already described the occurrence of sapphirine in this area.[1]

Vizagapatam, Kalahandi, Jeypore, Ganjam, and Orissa contain among them a petrological province whose geological characters have been established through the investigations of the Geological Survey of India. Operating in Ganjam in 1899-1900, Mr. F. H. Smith[2] found the western portion of that region to consist of an igneous complex associated closely with a series of metamorphosed sediments. The igneous rocks, which he considers as forming "the main foundation of the whole of the Ganjam district," consist of "garnetiferous granites and granulites" with "pegmatite, biotite gneiss, and hypersthene granulites, varying from acid to almost basic forms and representing the charnockite series." "The crystalline schists evidently represent a more or less metamorphosed series of ancient sedimentary rocks—the commonest form is a quartz-garnet schist always

[1] C. S. Middlemiss, Note on a sapphirine-bearing rock from Vizagapatam district, *Rec. Geol. Surv. Ind.*, XXXI, 1904, 38 - 42.

[2] F. H. Smith, *Gen. Rep., Geol. Surv. Ind., 1899-1900.*

rich in sillimanite." Much crushing and folding is spoken of, large masses of the para-schists being found as bands within the igneous rocks.

One of the authors of this paper, Dr. T. L. Walker, working in the neighbouring mountain region of Jeypore zemindari,[1] found igneous rocks varying greatly in acidity which he believes to be identical with charnockites.[2] The following season in the adjacent State of Kalahandi [3] charnockites were again found, which apparently together with those of the previously studied Ganjam and Jeypore districts, formed part of a single great massif. With regard to the sillimanite bearing schists which appear to be invariably associated with the underlying complex, he wrote :—" Apparently these isolated outcrops are remnants of a once continuous arch of altered sediments covering the great igneous massif of charnockites and associated rock which extends almost from the Godavari to the Mahanadi."

The massif referred to by Dr. Walker extends as an ellipse 250 miles long and 60 wide in a direction parallel to the adjacent coast of the Bay of Bengal, and includes portions of the states and districts mentioned above. Together with its covering of metamorphosed sediments it forms a denuded plateau 3,000 or 4,000 feet in altitude which is completely carved into hills and valleys, the summits of the latter standing at approximately equal elevation.[4]

The rocks here considered were collected from a small area that may be defined as lying near the villages of Gangrez Madgul, Ontali, and Pader in Madgul taluq, Vizagapatam district, and some distance within the south-eastern border of the charnockite massif. Pader lies in north latitude 18° 4′ and east longitude 82° 42′ 30″. Large neighbouring areas of charnockite occur, but in the immediate vicinity of these villages the predominant formation is the khondalite or sillimanite, bearing para-schists through which run narrow, interrupted bands of gneissoid granite lying parallel to one another and to the major axis of the massif. These bands are probably the exposed crests of folds in the igneous foundation from which the sedimentary covering has been removed by denudation. The specimens were taken in the

[1] T. L. Walker, *Gen. Rep. Geol. Surv. Ind.*, *1899-1900.*

[2] T. H. Holland, *Mem. Geol. Surv. Ind.*, XXVIII.

[3] T. L. Walker, Geology of Kalahandi State, *Mem. Geol. Surv. Ind.*, XXXIII.

[4] F. H. Smith, *loc. cit.*

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vicinity of these bands, and in a number of cases from their extremities.

(*a*) Ultra-basic spinel-bearing rocks.

Specimen 16·174, obtained near Panasput, is a massive black rock of specific gravity 4·02, resembling a magnetic iron-ore in the hand specimen. Upon microscopic examination, however, it is found to consist of green spinel and magnetite with accessory quantities of biotite, sapphirine and a few grains of a colourless, highly refracting mineral. Spinel is the predominate constituent and occurs as large, irregular, isotropic grains of deep green colour crowded with particles and feathery aggregates of magnetite. In the immediate vicinity of each magnetite particle the spinel is paler and more transparent than elsewhere. (Pl. 2, fig. 2.) Occasionally the iron-ore inclusions are rudely idiomorphic. Biotite occurs in well-formed plates, possesses a strong brown pleochroism, and is quite free from signs of crushing or strain. Sapphirine is subordinate in amount, appearing as small rounded grains of deep blue colour and strong pleochroism. Scattered sparingly through the sections are minute, sometimes nearly hexagonal, particles of limpid transparency, high relief and bright polarisation tints which may be corundum.

Upon chemical analysis this rock yielded the results given in column V of a subsequent page. Both mineralogically and chemically it bears considerable resemblance to the small group of igneous rocks termed ultra-basic segregations, rocks of low acidity found in association with gabbros and norites. For the sake of comparison, an analysis of a segregation of this character found in association with gabbro in Finland is cited in the adjacent column VI. The low percentage of silica and large quantities of TiO_2 and iron oxides are characteristic of both. G. H. Williams has described [1] rocks of similar nature occurring about the margins of a norite area in New York State.

As recorded by Mr. Middlemiss, who collected this specimen, it was obtained near the contact between the charnockites and khondalites, hence, if igneous in origin, it must be related to the former. In his study of the charnockites T. H. Holland has represented the extent of magmatic differentiation by creating four divisions according to acidity, as represented by the analyses quoted in columns I to IV.

[1] G. H. Williams, *Am. Jour. Sc.*, XXXIII, 1887.

Accompanying this decreasing acidity is a change in the mineralogical composition; quartz and felspar successively diminish and disappear, to be replaced by pyroxenes, olivine, and spinel. Consequent to this the specific gravity rises from 2·67 to 3·37. The principal features of chemical variation are the decreasing percentages of silica and accompanying increases in iron oxides, magnesia, and alumina.

From a rock possessing a specific gravity of 3·37, composed of hypersthene, augite, iron-ores, olivine, and spinel, and the chemical compositions given in column IV, to a rock such as 16·174 is a longer step than between any consecutive pair of types given by Mr. Holland. However, this gap is bridged by another specimen, 16·172. This consists of pyroxene, spinel, and biotite, with smaller amounts of sapphirine, sillimanite, and iron-ores. Its structure is that of a massive rock and its density 3·50. The chemical composition has not been determined, but may be considered from mineralogical evidence and density as intermediate between those given in columns IV and V.

That both 16·172 and 16·174 are related to the charnockites is further suggested by the optical likenesses of their pyroxenes to those of the characteristic charnockites. On the contrary, the surprising richness in alumina and the presence of sapphirine and sillimanite, which are unknown in pure charnockites, do not agree with this conception. In the following paragraph reasons will be given for considering them basic and ultra-basic members of the charnockite series that have been modified through contact action with the aluminiferous body now to be described.

(*b*) Sillimanite schists.

Specimen 16·173 is a light greyish brown, granular rock composed very largely of well-crystalllized silimanite. Scattered irregularly throughout this paler body are fragments of black rock material identical with the previously described spinel rocks. The hand specimen is imperfectly schistose; its density 3·31. The sillimanite exists as small square prisms of grey brown colour, but colourless in thin sections. Though usually devoid of pleochroism, some sections exhibit faint change of tint in polarised light. Cross sections are sharply rhombic with angles of nearly 90° and possess one series of distinct cleavage planes running diagonally. In all observed cases the extinction direction was inclined towards these planes, which must be regarded as pinacoidal, and thus do not seem to possess the rhombic character ascribed to sillimanite. Longitudinal sections appear

full of delicate rod-like inclusions arranged parallel to the vertical axis. The specific gravity of the mineral is close to that commonly found for sillimanite.

Neglecting the included fragments of spinel rock which are apparently not original constituents of this schist, the remaining material is almost altogether sillimanite, and would yield analytical results resembling a composition of sillimanite itself, *i.e.*, a body low in silica, alkalies, lime, and iron, but rich in alumina, thus essentially characteristic of sedimentary bodies. In the immediate locality where these specimens were obtained are the khondalites, regarded generally as metamorphosed sediments and distinguished by the presence of sillimanite. In all likelihood 16·173 is a variety of khondalite peculiarly rich in sillimanite.

(*c*) Intermediate rocks rich in sapphirine and spinel.

The relationship between the above two groups is well indicated in the composite specimen 16·171. It consists of sillimanite schist and black spinel-bearing rock in actual contact, these forming opposite ends of the hand specimen. The sillimanite material contains a larger proportion of the dark fragments than 16·173. Thin sections of this dark material show it to differ from 16·174 and 16·172 only in the proportions of its mineral constituents. Sapphirine is the predominant component, forming large, irregular grains rarely exhibiting a partial crystal outline and containing cubic or rounded inclusions of spinel. Biotite with pleochroism as described for 16·174 is in considerable quantity and shows crushed edges and undulatory extinction. In small patches and never in contact with spinel are transparent, idiomorphic crystals of sillimanite. Spinel is comparatively subordinate. Magnetite grains lie scattered among the coloured minerals.

Specimens 15·808 and 16·168 (both from the same rock-mass) differ from the dark portion of 16·171 only in being schistose and in minor details, so that an analysis of the latter given in column VII fairly represents the group. A comparison with the analysis of 16·174 and the inferred composition of 16·173 shows that all its constituents lie intermediate in amount or that the same chemical result might be obtained by analysis of a mixture made from sillimanite schist and ultra-basic charnockite materials in certain proportions. The union of these substances has apparently been brought about in nature through the absorption of an already deposited aluminous sediment

by an intruded basic charnockite magma. The basicity of this magma has varied from point to point. Specimen 16·168 has resulted from a more acid intrusion than 16·171, since the former bears a considerable amount of pyroxene and less iron-ore vestiges of the absorbed matter not assimilated remain in the form of sillimanite crystals. The most noticeable feature, however, has been the replacement of the predominant spinel by sapphirine. The general result has been a metamorphic zone between the charnockites and khondalites characterised by the presence of sapphirine.

Specimens 15·808 and 16·168, which are from the same rock-mass, belong to this zone, and it will now appear that 16·174 and 16·172 cannot be regarded as pure igneous forms, but, as indicated by their high alumina content and the presence of sapphirine, also belong to the metamorphic zone. However, modification has not proceeded far in these cases and the original igneous characters remain sufficiently distinct.

	I.	II.	III.	IV.	V.	VI.	VII.
SiO_2	75·54	63·77	53·38	46·86	3·60	4·08	35·90
TiO_2	...	...	...	...	4·57	14·25	...
Al_2O_3	13·75	16·30	19·38	9·80	45·97	6·40	32·91
FeO / Fe_2O_3	4·99	7·49	15·39	16·35	40·23	34·58 / 33·43	9·16
MgO	·69	2·49	2·79	18·08	7·36	3·89	21·40
CaO	·94	6·33	7·68	9·57	·92	·65	...
K_2O	3·34	1·21	...	...	...	·15	...
Na_2O	1·55	3·68	...	...	...	·29	...
H_2O	·28	...	...	·67	...	1·32	·60
MnO	...	...	...	...	...	·45	·40
Cr_2O_3	...	...	...	...	...	·20	...
P_2O_5	...	...	...	...	...	·02	...
TOTAL	101·08	101·27	98·62	101·33	102·65	99·71	100·37

I, II, III, and IV.—T. H. Holland, *Mem. Geol. Surv. Ind.*, XXVIII.
V.—Analysis of rock No. 16·174.
VI.—Peterson, *Geol. Foren. Ford.*, XV, p. 49.
VII.—Analysis of rock No. 16·168.

The mineral association found in the above described metamorphic zone is an unusual one and some attention was given to the detailed study of the different species.

Sapphirine occurs everywhere throughout the zone in the form of irregular or rounded translucent grains of deep blue colour. Only two fragments with partial crystal outline have been observed. One of these seen in thin section possessed two rectilinear edges,—orthopinacoidal and a prismatic. Twinning was not observed. Most sections are traversed by a single distinct series of cleavage lines parallel to the clinopinacoid, also by heavy irregular cracks.

Optically the mineral behaves like members of the monoclinic system. The optic plane lies in the clinopinacoid and the extinction angle is about 15°. This latter was determined by means of acicular or sharply cubic inclusions of spinel whose edges coincide with the vertical and orthoaxes: the maximum inclination of these with the direction of extinction was 15°. Sections normal to the acute bisectrix show, in convergent light, a biaxial inclined interference figure: the same sections when tested with the quartz wedge indicate a negative optical character. In parallel polarised light they remain deep blue, changing only from navy to Berlin tints: prismatic and pinacoidal sections vary from deep blue to greenish orange. The birefringence is low, the relief about equal to that of augite. Suitable specimens for determining values for α, β and γ and for the optic angle could not be obtained. The accompanying diagram illustrates the optical character.

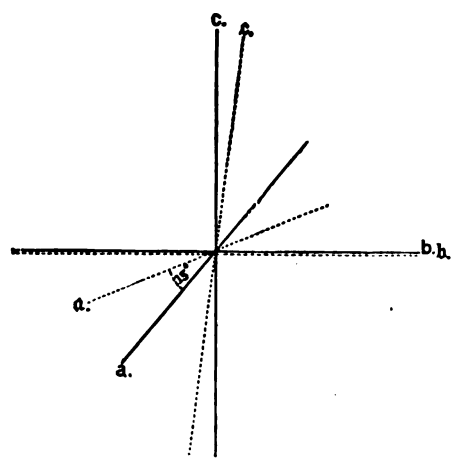

FIG. 1.

Specimen 16·168 was crushed, sifted, and the sapphirine particles separated by means of a supersaturated Klein's solution. Thus a quantity of 10·5 grammes was obtained, which, after treatment with hydrofluoric acid to remove any thin scales of adherent mica, was examined under the microscope. The specific gravity was determined to be 3·542 by using a pycnometer and the entire sample. Its hardness lies between that of quartz and topaz.

Chemically, sapphirine is resistant and shows no sign of natural alteration. It is unattacked by acids except hot hydrofluoric, and then only when in a finely pulverised condition and after prolonged digestion. It is slowly decomposed by alkali carbonates, but readily by fusion with potassium bisulphate or microcosmic salt. The average of duplicate analyses is given in column VI below. Of the other analyses cited, VII is of material from the same rock, while the remainder relate to sapphirine from Fiskernäs in Greenland. The Indian specimens seem to possess relatively higher percentages of iron oxides and less of magnesia. Corresponding to this chemical difference is a noticeable variation in physical properties. The Fiskernäs sapphirine exhibits a less intense pleochroism, varying from pale blue to yellowish green. Also its specific gravity as given by Ussing is considerably less.

	I.	II.	III.	IV.	V.	VI.	VII.
SiO_2 . .	14·3301	14·86	14·76	12·95	12·83	14·56	12·55
Al_2O_3 .	63·3036	63·25	63·28	64·44	65·29	60·49	67·06
Fe_2O_3 . .	4·0092	1·99	1·65	1·66	·93	7·65	16·21
FeO . .					·65		
CaO . .	·0375	...	...	...	...	..	·17
MgO . .	16·9683	19·28	19·75	19·83	19·78	17·13	3·97
Loss . .	·4920	...	...	·34	·31	·56	·25
MnO . .	·052	...	...	...	...	...	...
TOTAL .	100·0000	99·38	99·44	99·22	99·79	100·39	100·75

I.—Stromeyer, Untersuch über die Mischung. d. Min., I, 391.
II.—Damour, Zeit. für K., XV, pp. 598—615.
III.—Schluttig „ „ „ XIII, p. 74.
IV.—Lorenjez, Meddelelser on Greenland, VII, p. 15.
V.—Ussing, Zeit für K., XV, pp. 598—615.
VII.—Middlemiss, *Rec. Geol. Surv. Ind.*, XXXI, Pt. I, p. 40.

Spinel.—This mineral is a prominent constituent in the sapphirine schists at Fiskernäs and constantly found in those of Vizagapatam. It is recorded in the norite members of the charnockite series and occurs only in those metamorphic rocks that have had an igneous source. In the neighbouring modified khondalites it appears to have been introduced in a solid condition by mechanical movements and cannot be regarded as native to those para-schists.

Except as cubic inclusions in sapphirine, it exhibits no crystal form, occurring always in large irregular grains, which seem to have crystallized at the same time as the magnetite particles with which it is crowded. (Pl. 2, fig. 2.) By transmitted light these grains are deep green in colour, the immediate neighbourhood of magnetite inclusions being lighter in colour, and more translucent. No cleavage is visible. Optically it is isotropic.

A sample for analysis was obtained by pulverising portion of rock No. 16·180, treating the powder with hydrochloric acid and, afterward, with a mixture of hydrofluoric and hydrochloric acids, washing, filtering, and drying the residue. The analytical result is given in column I on a following page. This places it in the pleonaste division of the spinel group next to hercynite. Comparison with Steenstrup's results from Fiskernäs the spinel shows a lower percentage of magnesia, a condition that holds for the sapphirine and probably sillimanite also.

As already pointed out by Middlemiss (*loc. cit.*, p. 39), the geological and chemical conditions at Fiskernäs and Vizagapatam show a similarity so remarkable that sapphirine and its associates in both places seem to have been governed by similar conditions. Giesecke[1] first in 1809 discovered the Greenland occurrence which has been described geologically by Steenstrup.[2] Later Ussing[3] made a complete investigation of the mineral association.

The sapphirine-bearing schists occur as lenticular masses enclosed in gneiss or mica schist. One variety of material forming these lenses consists of bronzite, sapphirine, and spinel, with accessory biotite; another of sapphirine, gedrite, monoclinic hornblende, and biotite, with smaller amounts of anorthite, cordierite, and kornerupin. In the former association sapphirine is devoid of crystal form, deep blue in

[1] Giesecke's Mineralogiske Rejse, p. 153.
[2] Meddelelser on Greenland, VII, p. 15.
[3] Zeit für., XV, pp. 598—615.

colour, and has deep blue to yellowish green pleochroic tints, while in the other it is partially idiomorphic, pale blue, and varies from bright blue to almost colourless in parallel polarised light.

The description for the first type would hold equally well for the Vizagapatam rocks, just described. In general appearance hand specimens from both regions are much alike. Ussing's second type is not so well represented among the Indian rocks, yet in specimens 16·182, 16·189 sapphirine is found sparingly in a metamorphic schist consisting of hypersthene, biotite, cordierite, sillimanite, and accessory rutile. Here it is pale blue and of weak pleochroism. It is small in amount and associated with fragments of spinel rock which appear to have been introduced in a solid state of dynamic activities. The true birthplace of sapphirine as evidenced by the Indian rock specimens is the metamorphic zone at the contact between the khondalites and spinel-bearing magmatic segregations.

It has been already shown that in chemical composition, specific gravity, and mineralogically, the metamorphic sapphirine-bearing zone is the result of intermixture of khondalite schist and segregated spinel rock, the product being rich in alumina and magnesia and iron oxides, but low in silica. Lime is practically absent in all these. Steenstrup's examination of the sapphirine rocks at Fiskernäs yielded the same conclusions. A comparison of 16·174 and 16·171 offers the fact that, though consisting of the same minerals, spinel and sapphirine are in inverse proportions, the former occupying a prominent place in 16·174, but appearing only vestigially in 16·171 as inclusions in sapphirine. In 16·172 sapphirine forms reaction rims around spinel grains. In fact, sections of 16·174, 16·172, 16·171, and 16·168 in that order would present a progressive series in which spinel is being replaced by sapphirine. The small amount of sillimanite in any of these, *e.g.*, 16·171, cannot account for all the absorbed khondalite, so the most of it has evidently been transformed mineralogically, and as the only notable quantitative evidence of such transformation is the replacement of spinel by sapphirine, the absorbed khondalite material must have been employed in the production of this alteration.

A comparison of the compositions of spinel, sapphirine, and sillimanite indicates to a marked degree the intermediate position that sapphirine bears towards the others in all its constituents, a fact which chemically substantiates the view that it is really a product of their interaction.

	I.	II.	IIIA.	IIIB.[1]
SiO_2 . .	·10	14·56	37·36	30·90
TiO_2 . .	None	...	...	...
Al_2O_3 . .	65·02	60·49	58·62	46·79
Fe_2O_3 . . / FeO . .	22·02	7·65	2·174	2·02
CaO .	trace	...	...	...
MgO . .	13·16	17·13	·398	19·46
MnO . .	trace	...	...	...
Loss . .	...	·56	·428	1·30
TOTAL .	100·30	100·39	98·984	100·47

I.—Analysis of spinel from specimen 16·180.
II.— " " sapphirine from specimen 16·168.
IIIA.— " " sillimanite: Dana, Manual of Mineralogy.
IIIB.— " " Kornerupin: Steenstrup, Meddelelser on Greenland; VII, p. 20.

(*d*) Rocks free from both spinel and sapphirine.

Under this group are included rocks varying in specific gravity from 2·67 to 2·93, composed in the main of sillimanite, cordierite biotite, and hypersthene, but free, or almost free, from iron-ores, spinel and sapphirine. From this it appears as if they represent a phase in which the aluminous participant was relatively more abundant than the ferromagnesian. The minerals are fairly acid and contain about fifty per cent. of silica.

Structurally they are medium grained rocks at times slightly foliated, but usually massive. Under the microscope one observes that the sillimanite and biotite have crystallized early and are more or less idiomorphic. Between these have formed the cordierite and the hypersthene. Later pressure has bent the biotite, brought out very marked strain phenomena in the cordierite, and given the whole mass the ragged appearance characteristic of much pressed rocks.

[1] In this connection the composition of Kornerupin, the Fiskernäs equivalent of sillimanite, is cited.

pical of this group are specimens 16·185, 16·189, 16·184, 16·169, d 15·809.

The different mineralogical constituents present some interesting ιtures worthy of record.

Cordierite.—In many of these rocks cordierite is the most abundant nstituent. It is never idiomorphic. Four types of this mineral are sily distinguished in the slides studied. In sections such as those ιde by Voigt and Hochgesang no pleochroism is observed, though in ecially thick sections the usual blue to yellowish green colours are served. *First type.*—The best mark for the identification of the rdierite lies in the swarms of tiny yellowish crystal inclusions ιich for certain vibrations of the polariser surround themselves with ry beautiful pleochroic aureoles. In other instances, the inclusions e colourless, and may then be regarded as zircon. The yellowish clusions are often well-formed crystals with straight extinction. ross sections are rectangular, and as they are marked by the presence two equally perfect cleavages, the mineral may be regarded as ιtile. The aureoles are most brilliant when the vibration direction the polariser coincides with one of the extinction directions of the ›rdierite. If the section be revolved through an angle of 90° from ιis position the aureoles disappear completely. *Second type.*—Here ιclusions are as a rule absent, and the chief diagnostic characteristic es in the general resemblance of the mineral to plagioclase both in winning and polarisation tints. From this mineral, it may be distinuished by the habit of two or even three systems of twinning bands ntersecting at angles of 60° and 120°. Such intersections would orrespond to basal sections of this rhombic mineral with interpenerating polysynthetic twinning with the prism (110) as twinning plane. Pl. 1, figs. 1 and 2.) *Third type.*—Here the cordierite is free from ›oth twinning and inclusions. It is particularly well developed in ections of much pressed rocks where it forms aggregates of grains or ιt times larger strained individuals resembling quartz, under similar conditions. An occasional tiny inclusion or a trace of twinning serves to demonstrate that this really is cordierite. *Fourth type.*—In this instance the cordierite appears in a form not hitherto described. It consists of an intimate intergrowth of two minerals polarising in grey tints, the two parts extinguishing separately as in the case of the micropraphic quartz felspar intergrowths. Here, however, there are no sharp edged boundaries, the whole aggregate in thin section

presenting the appearance of a vermicular intergrowth. The high power occasionally reveals polysynthetic twinning in the individual vermicular constituent minerals. This may at times be observed optically continuous with the cordierite of the second type, and then one part of the intergrowth extinguishes with one part of the twin, and the second part with the second of the twinned aggregate. In other cases small inclusions with the characteristic aureoles mark the aggregate as at least in part cordierite. (Pl. 2, fig. 1, and Pl. 3, fig. 1.)

Sillimanite.—In sections of this rock sillimanite plays a very important part. There are three fairly well-characterised varieties. The first consists of idiomorphic stout prisms usually marked by one set of parallel cleavages. Cross sections polarise in very dark grey tints or are sometimes almost isotropic. The interference figures are biaxial with very small optical angles. When slightly inclined so as to make the position of extinction quite sharp, these sections do not extinguish parallel to the one set of cleavages, a fact which seems to indicate that the mineral is not rhombic, but possibly monoclinic or triclinic. Sections in the prismatic zone polarise in brighter colours somewhat similar to those of quartz of the same thickness. Such prismatic sections may show cleavage or not according to the direction in which they are cut. The acute bisectrix is the axis of least elasticity, and the mineral is consequently positive. This type of sillimanite has been frequently described, but in the rocks here described the crystals are unusually large and well formed. *The second* variety consists of acicular aggregations of small slender crystals well individualised and easily distinguished from the *third type* which is found in fibrolitic felty intergrowths sometimes constituting a large part in the rock.

Hypersthene—is present as a chief mineral in many of the sections and is readily recognized by its strong pleochroism, sky-blue to red or red-brown. The extinction as measured on the cleavage is frequently inclined, a fact that has been noted by the writer in many so-called hypersthene rock. There can be little doubt that there is a monoclinic pyroxene with the pleochroic tints above mentioned. It is not, however, so clear as to whether there is apart from this monoclinic mineral a really rhombic pyroxene with these types of pleochroism. In many sections of the Indian charnockites, as well as in norites from Germany and Canada, the same observations have been recorded. Notwithstanding this inclined extinction on sections showing only

parallel cleavages, *viz.*, sections from the prismatic zone, it is desirable to continue to refer to this mineral as hypersthene, unless it be demonstrated that there is also a rhombic pyroxene with the properties usually assigned to hypersthene, and then it may become necessary to refer to this really common monoclinic type as clino-hypersthene.

Sometimes the hypersthene forms large individuals spangled with the well-known inclusion plates, but more frequently it consists of elliptical grains and slender crystals strung together and arranged in more or less parallel series of inclusion chains fairly well packed together. These sometimes stretch out from somewhat larger grains. This latter type appears to be the product of later changes in the rock as the strings and chains penetrate a variety of minerals and follow the boundaries between the adjoining grains. It seems to be an instance of secondary formation, resulting from the mingling of the spinel and sillimanite substances, similar in structure to the formation of secondary green hornblende by the action of plagioclase on ferromagnesian minerals. (Pl. 3, figs. 1 and 2.) In order to show the chemical relationship between this mineral and the standard hypersthene, a chemical analysis was made on carefully separated material.

The mineral was separated in the manner described for sapphirine and a pure sample of about 8 grammes obtained. The entire quantity was used for a determination of specific gravity, a value of 3·386 being obtained. Its hardness lies slightly below that of orthoclase.

Duplicate analyses yielded the following results :—

	I.	II.	Average.
SiO_2	49·81	49·74	49·77
Al_2O_3	13·16	13·20	13·18
FeO	10·53	10·93	10·73
MnO	·37	·42	·40
CaO	trace	trace	trace
MgO	27·98	27·73	27·86
Loss	·15	·17	·16
TOTAL .	102·00	102·19	102·09

These proportions, the density and optical features would place it in the bronzite division of orthorhombic pyroxenes, but the percentage of alumina is exceptionally high.

The bent and torn biotite fragments while constituting a large part of some of these rocks call for no special comment. In some of the lighter specimens such as 16·184 much pressed quartz constitutes a large part of the rock-mass. Small proportions of the opaque iron-ore and of green transparent spinel feathered by opaque inclusions complete the list of minerals present.

(*e*) Rocks free from sapphirine, but containing spinel.

In contrast to the light coloured rock dealt with under (*c*), the rocks of the present group are bluish black to brown in colour on fresh fracture with a strong tendency to rusty weathering on exposed surfaces. They usually show some trace of banding, though seldom of a well-foliated or schistose type. (Specimens 16·175, 16·176, 16·177, 16·179, 16·181, 16·183, and 16·187.)

These rocks are apparently intermediate between the rocks rich in spinel and sapphirine and those just described which are free, or nearly free, from both these minerals. The thin sections in the present suite show considerable proportion of dark minerals. The three suites of rocks seem to be related to one another—they constitute a series or a part of a series of which mention has already been made—in which the end members are ultra-basic spinel rocks and the sillimanite schists.

Mineralogically these rocks are made up of the same minerals as the light coloured rocks dealt with under (*c*), except that they are more basic and are marked by the presence of a considerable proportion of spinel. Cordierite and biotite, which are very prominent in the former class, are here quite subordinate. Sillimanite becomes relatively more abundant, and spinel makes its first appearance. From these observations it is apparent that the dark rocks are nearer to the proposed spinel prototype. Some of the slides are fairly rich in hypersthene. As this mineral usually contains about 50 per cent. silica it may be regarded as the most acid of the silicates present.

Structurally there is little to note. A greater schistosity is marked in the thin section by a parallel arrangement of the constituents, particularly of the aggregate of hypersthene grains. The spinel abounds in feathery opaque iron-ore grains which are surrounded by

clearer green areas of spinel—remote from the iron-ore the spinel contains swarms of black microscopic inclusions of iron-ore. The grains of spinel are almost invariably surrounded by a zone of colourless limpid sillimanite, and beyond this often narrow zone lies the area occupied by the so-called hypersthene, the vermicular twinned intergrowths of cordierite and needles, and stout prisms of sillimanite. (Pl. 3, fig. 1.)

In default of a series of chemical analyses of these rocks it may be interesting to note the relationship between the classification as detailed in this paper, largely microscopical, and the grouping of the rocks as shown by their specific gravities.

	Register No.	Specific gravity.	Specific gravity of group.
1. Spinel rocks	16·174 16·180	4·05 3·78	3·91
2. Sapphirine rocks	16·172 16·171 16·192 16·191 16·168 15·808	3·69 3·45 3·41 3·31 3·27 3·16	3·38
3. Spinel-bearing, but free from sapphirine.	16·179 16·175 16·181 16·183 16·177 16·176 16·187	3·40 3·34 3·30 3·17 3·14 2·94 2·86	3·16
4. Free from sapphirine and spinel	16·185 16·189 16·184 16·169 15·809	2·93 2·81 2·74 2·71 2·67	2·76
5. Rocks with traces of sapphirine and spinel.	16·186 16·190 16·182 16·173	3·31 3·31 3·05 3·31	3·25

III.—CONCLUSIONS.

1. The occurrence of the Indian sapphirine rocks is practically identical with that of Fiskernäs in Greenland. They appear to be the result of mingling and subsequent metamorphism of ultra-basic igneous borders and very aluminous para-schists rich in sillimanite.

2. The cordierite present in the thin sections appears in a number of types, some of which appear to be new to petrography.

3. A member of the pyroxene family of minerals possessing the pleochroism of hypersthene, but, with oblique extinction, is present in a number of the rocks examined. If there be really a rhombic pyroxene with the characteristics usually ascribed to it, then this Vizagapatam pyroxene may require a distinct name, and the writers suggest that it be then known as clino-hypersthene.

IV.—EXPLANATION OF MICROPHOTOGRAPHS.

PLATE 1, FIG. 1.—Cordierite containing zircon crystals surrounded by pleochroic aureoles. Polariser only. Section from specimen 16·186. (× 23 diameters.)

PLATE 1, FIG. 2.—Same section as No. 1, showing well-twinned cordierite. Nicols crossed. (× 23 diameters.)

PLATE 2, FIG. 1.—Vermicular intergrowth of cordierite. Section from specimen 16·183. Nicols crossed. (× 23 diameters.)

PLATE 2, FIG. 2.—Spinel rocks 16·180, showing inclusions of magnetite in spinel with clear zones around these iron-ore grains. Ordinary light. (× 40 diameters.)

PLATE 3, FIG. 1.—Spinel grains (black) surrounded by clear zone of cordierite beyond which is a narrow zone of hypersthene. The main light coloured part of the section is vermicular cordierite, while the particles of intermediate tint are hypersthene. Ordinary light. Specimen 16·181. (× 40 diameters.)

PLATE 3, FIG. 2.—Spinel (black) surrounded by sapphirine intermediate in tint, beyond which is hypersthene in still lighter tints. Specimen 16·172. Ordinary light. (× 40 diameters.)

NEPHELINE SYENITES FROM THE HILL TRACTS OF VIZAGAPATAM DISTRICT, MADRAS PRESIDENCY. BY T. L. WALKER, M.A., PH.D., *University of Toronto.*

THROUGH the kindness of the Director of the Geological Survey of India the series of rocks here described was sent me for laboratory study. They were collected during the field season 1901-02 by Mr. C. S. Middlemiss, Superintendent of the Geological Survey of India, while making a survey of that region.

The field relationships of these rocks appear to be those of igneous instrusions occurring along with other gneissoid igneous types (charnockite and biotite gneissoid granite) forming part of the great boss extending from the Godavari to the Mahanadi, constituting for two hundred and fifty miles the northern portion of the Eastern Ghauts. This giant eruptive is overlaid in part by metamorphosed sediments, principally by khondalite, and to a less extent by laterite. The specimens studied were collected a short distance north-east of the town of Koraput.

These rocks are readily recognized as nepheline-bearing, even macroscopically, by the depressions on the weather surface, due to the leaching out of the somewhat soluble nepheline, and on freshly broken surfaces by the oily lustred, light coloured grains of this mineral.

The specimens forwarded to me are of two main types, the first light in colour, somewhat banded and streaked by dark drawn out bands and patches of biotite and hornblende (specimens 16·164); the second composed of large porphyritic crystals of nepheline enclosed in a mass of mylonitic material, which has apparently been formed by the application of considerable pressure to a very coarse pegmatitic variety of the rock containing phenocrysts of nepheline as large as walnuts (specimens 16·164). Both are probably of the same massif though the pressure which lent to the first only an indistinct gneissoid structure without the least sign of granulation caused in the second cataclastic structures which are readily apparent.

The first mentioned type when examined under the microscope is seen to belong to that class of nepheline syenites containing relatively

more biotite than hornblende, approaching in this regard the typical miaskites of the Urals, from which it would be impossible to distinguish it without the aid of the microscope. Greenish-brown hornblende, brown biotite, and magnetite grains more or less idiomorphic make up only a very small fraction of the rock-mass. Anhedra of nepheline and large irregularly rounded grains of felspar constitute the major portion of the rock.

As seen under the microscope, the most interesting constituent is the felspar. No twinning is to be observed. The irregular masses of this mineral when examined with crossed nicols break up into two parts—into a series of similarly oriented lenses included in a ground-mass which for the rest of the grain possesses a uniform orientation. This suggests the micro-perthitic structure, though no twinning is observed in any of the included lenses. That it is really a complex of the ordinary perthitic type despite the absence of twinning is proved from the accompanying analysis. In the matter of felspars our Indian miaskite differs in microscopic appearance from the type from the Urals in which both plagioclase and orthoclase are present as distinct individuals, though never in the form of perthitic intergrowths.

With a view to determining the approximate proportion of nepheline present in the rock a small portion of the prepared powder of 16·164 was treated with warm dilute hodrochloric acid. In this way the nepheline and calcite, and possibly in part the very small quantity of biotite, were decomposed. The soluble portion was filtered off and the residue treated with caustic potash. The residue after this second treatment when dried and weighed was found to constitute only 61·16 per cent. of the original powder. The loss in dissolved minerals—almost entirely nepheline—would therefore represent 38·84 per cent. corresponding to a nepheline content of about 37 per cent.

Calcite is a somewhat unusual constituent for a decidedly igneous rock as fresh as the specimens in question. It forms cleavable well-twinned anhedra, which, judging from the determined amount of carbonic acid, 55 per cent., makes up about one per cent. of the whole rock. It can hardly be regarded as other than an original constituent of the rock-mass. Calcite occurring in the nepheline syenites of Sivamalai, South India, has been similarly regarded by T. H. Holland[1] as an original constituent of the igneous rock.

[1] Holland. The Sivamalai series of Elæolite-syenites and Corundum-syenites, *Mem. Geol. Surv. Ind.*, XXX, 1901, pp. 197 and 214.

The result of the analysis of 16·164 is recorded in I: miaskite from the Urals is given in II:[1] in III is presented an analysis of a closely related rock from Sivamalai.[2]

	I.	II.	III.
SiO_2 . . .	52·60	56·26	55·68
Al_2O_3 . . .	26·60	23·59	23·81
Fe_2O_3 . . .	·91	·85	4·84
FeO . . .	2·21	2·61	
MgO . . .	·51	·27	·65
CaO . . .	1·89	·54	1·69
Na_2O . . .	7·06	7·77	9·23
K_2O . . .	6·94	5·72	5·16
CO_2 . . .	·55	1·37	...
TiO_2 . . .	...	·47	...
MnO . . .	...	·09	...
Graphite . .	...	...	·58
H_2O . . .	·61	·37	·34
TOTAL .	99·88	99·91	101·98
S. G. . . .	2·65	...	2·593

The position of the miaskite according to the system of the authors of a "Quantitative Classification of Igneous Rocks"[3] is a peculiar one. By the method of arrangement in question rocks of similar chemical composition are brought together, without regard to the structure. In a general way the molecular proportion of the ferro-magnesian minerals is less than one-seventh of that of the light

[1] Karpinsky, Guide, VII, Cong., G., Inter., V, p. 22, 1897.
[2] *Mem. Geol. Surv. Ind.*, XXX, p. 181.
[3] Cross, Iddings, Pirrson and Washington. Quantitative Classification of Igneous Rocks.

coloured constituents. This brings it into the large class, Persalane. The richness of the rock in alumina refers us to sub-class II. In short, such considerations as these, based entirely on the results of the chemical analysis, places the Vizagapatam miaskite as follows:—

Class I, Persalane.
Sub-class II.
Order 7.
Rang 2.
Sub-rang 3.

It would not be surprising if this miaskite should turn out later on more thorough field study to be associated with rocks bearing corundum. Judging from the very high proportion of alumina as well as from the known mineralogical and petrological associations of similar rocks in the south of India, in central Ontario, and in Montana, we are in a measure warranted in anticipating such occurrences of valuable corundum deposits.

Associated with these typical light coloured nepheline rocks occur darker border types suggesting in hand specimens gabbros or diorites 16·164. As seen under the microscope, the rock is composed largely of a yellow-brown strongly pleochroic hornblende, and to a less degree of plagioclase, biotite, and magnetite. After corroding with acid and staining, one observes that numerous small rounded grains, which polarise in dark grey tints, have been attacked by the acid and hold the stain. These small grains are therefore nepheline and the rock becomes a theralite in which the dark minerals are hornblende and biotite to the exclusion of pyroxene. Rocks of this type occur in various parts of the world, usually in association with nepheline syenites, forming basic border segregations. The high specific gravity, 3·08, corresponds to the general basic mineralogical composition.

THE STRATIGRAPHICAL POSITION OF THE GANGAMOPTERIS BEDS OF KASHMIR. BY H. H. HAYDEN, B.A., F.G.S., *Superintendent, Geological Survey of India.* (With Plates 4—9.)

DURING the past summer advantage was taken of the opportunity, afforded by a visit to Kashmir, to spend a few days at Khunmu with a view to ascertaining the true stratigraphical position of the plant-bearing beds exposed on the Risin spur at the mouth of the Nagowan ravine.

Fossils were first found in these beds by Dr. Noetling in 1902.[1] His collections, described by Professor A. C. Seward and Dr. A. Smith Woodward,[2] comprised species of *Gangamopteris*, *Amblypterus*, and *Archegosaurus;* all the species were new, but the fishes and the Labyrinthodont proved to have close affinities with lower Permian and Coal-measure forms. The importance of this evidence of the Palæozoic age of *Gangamopteris* in India had already been pointed out by Mr. Holland,[3] but it still remained to ascertain the precise relationship of these plant-bearing beds to the fossiliferous marine sediments occurring in the same area. Unfortunately the outcrop from which Dr. Noetling's specimens were collected occurs on a small spur jutting out into the alluvial plain,[4] and the uppermost beds, in which most of the fossils were found, dip under recent fan deposits of unknown, but probably considerable, thickness, the nearest outcrop of the fossiliferous Zewan beds being over three-quarters of a mile distant.

Although it was assumed that the true stratigraphical position of the Gangamopteris beds was below that of the Zewan beds, this was not definitely ascertained by Dr. Noetling, and a subsequent visit was paid to the locality by Mr. R. D. Oldham, who not only re-examined the Risin spur, but also searched all the known fossiliferous

[1] T. H. Holland: *Gen. Rep. Geol. Surv. Ind., 1902-03*, p. 23 (1903).
[2] *Pal. Ind., New Ser.*, Vol. II, Mem. 2 (1905)
[3] *Op. cit.*, p. 22; also *Rec. Geol. Surv. Ind.*, XXXII, 153 (1905).
[4] F. Noetling: *Centralblatt für Min., Geol. und Pal.*, p. 129 (1904).

localities in the Vihi plain.[1] On the Zewan section, he found a band of black shale, with carbonised plant remains, which, in its method of weathering, resembles the matrix of the Gangamopteris beds of Risin.

Mr. Oldham, however, met with no determinable fossils at this horizon and was therefore unable to identify it directly with the Gangamopteris beds. It was consequently considered advisable that advantage should be taken of the first opportunity to re-visit the Khunmu area and make a further attempt to find the Gangamopteris horizon on a continuous section.

The Risin outcrop.

From the plan published by Dr. Noetling[2] it would appear that the plant beds occur as an isolated exposure between an outcrop of trap on the one hand and of the Zewan beds on the other, and separated from both by recent talus slopes and fan deposits: this, however, was found not to be an accurate representation of the area, and a plane-table sketch-map was therefore prepared, on a scale of 400 feet to the inch: a reduction of this is published on Pl. 4, fig. 1. Dr. Noetling's conclusions as to order of succession of the beds were based chiefly on the supposed concordance of dip in all the outcrops; our observations on this point, however, as well as on that of the relative positions of the outcrops, are mutually conflicting, and since reference will be made to the map from time to time, it has been considered advisable to reproduce also Dr. Noetling's plan (see Pl. 4, fig. 3). From the sketch-map it will be seen that the Gangamopteris beds form the end of a spur, lying at about four-fifths of a mile to the west-north-west of Khunmu and running down from a high hill composed of trap, and dip under the recent fan of the Nagowan stream (see also Pls. 5 and 6). The crest of this small spur constitutes the line of junction between the Gangamopteris series and the underlying trap: the junction is perfectly clear and the passage from the one series into the other, although rapid, is not abrupt.

The uppermost of the trap bands is a grey compact rock containing fairly numerous amygdules of (?) palagonite and chalcedony. It is much altered, but can still be seen to have had a glassy matrix and may have been an andesite: this cannot be determined without a much more detailed examination than I was able to make during the few days of my stay.

[1] R. D. Oldham: *Rec. Geol. Surv. Ind.*, XXXI, 5 (1904).
[2] *Op. cit.*, p. 133, fig. 2.

The trap is overlain by a bed about three feet thick, of green, shaly material; above this is a thin band of shale (8 inches) overlain by a bed (about 3′ 6″) composed of dark, almost black, crystalline limestone and black chert in intimate association: over these are carbonaceous shales (15—20′)—with an occasional thin band of black crystalline limestone—followed by a second bed of limestone and chert (10 feet), overlain by carbonaceous shale.

The two bands of carbonaceous shale correspond to beds 9 and 11, respectively, in the section given by Dr. Noetling[1] and it is in these that the fossils were found. The lower band appears to contain only *Gangamopteris* and that only in the uppermost layers, and it is the upper bed which has yielded the greater part of the rich collections made by Dr. Noetling, and more recently augmented by Mr. Oldham and myself. The greater productiveness of the upper band may be merely apparent, since the dip of the bed corresponds approximately with the slope of the hill-side and the outcrop is therefore very extensive (Pl. 6).

It will be seen from the sketch-map that on the south and east the exposure is bounded by recent deposits, whereas on the west and north it is in contact with the underlying trap: hence no younger beds are exposed in this locality.[2]

Section in Guryul ravine.

The nearest point at which sedimentary rocks are again found overlying the trap is in the Guryul ravine, the mouth of which lies at a little over a mile to N. 15° W. of Khunmu and 1,200 yards N. E. by N. of the Risin spur.[3] At the mouth of the ravine the trap is seen on the right-hand side of the stream and limestones with *Athyris*, *Productus*, etc., on the left: the interval between is covered with recent stream deposits and it is necessary to go some little

[1] *Op. cit.*, pp. 130, 131. His description of the lower band as "erdiger Kalkschiefer" does not accord with my observations; the matrix of the specimens of *Gangamopteris* that I obtained from this band is a black carbonaceous shale, quite free from calcareous matter. There may, however, be local variation.

[2] The section given by Dr. Noetling in the paper already referred to must be regarded as purely diagrammatic; the beds (2—11) are shown as dipping to the north, whereas their actual dip is E. S. E. at one end of the exposure and S. E. at the other.

[3] This ravine is readily recognised by the presence of two large chenar trees at its mouth: see Lydekker, *Mem. Geol. Surv. Ind.*, XXII, 131, 132 (1883), and Godwin-Austen, *Quart. Journ. Geol. Soc.*, XXII, 33 (1866).

distance up the gorge before an uninterrupted section is found. At about 300 yards above the mouth, a conspicuous spur runs down between the two main branches of the stream, and in the more easterly of these tributaries an uninterrupted section is found from the trap through cherts to the Gangamopteris series and the Zewan stage up to beds of undoubted Triassic age.

The uppermost trap band is a somewhat amygdaloidal rock, very similar to that of the Risin spur, but the overlying beds appear at first sight to differ markedly on the two sections. It has already been pointed out by Mr. Oldham that the beds in the Guryul ravine have suffered from crushing and faulting, and it is not easy to find a section free from disturbance, but at the point already defined the sequence appears to be a normal one ; it is as follows :—

Zewan beds.	7. Shale and limestone with *Bryozoa* and brachiopods.
Gangamopteris series.	6. Chert with thin bands of silky grey shale.
	5. French-grey shale and dark carbonaceous shale with intensely hard grey siliceous band.
	4. Chert, chiefly dark-blue and black, with pale, sometimes white, patches.
	3. Silky shale,—crushed, almost a phyllite.
	2. White chalcedony (novaculite).
	1. Amygdaloidal trap.

Comparison of Risin and Guryul sections.

At first sight there would appear to be little or no resemblance between this section and that of the Risin spur, but a closer examination of the individual beds soon shows that the sections have two peculiar and characteristic elements in common: these are the chert bands and the carbonaceous shale. The latter rock is remarkable for the fact that on fresh fracture it is intensely black with numerous black shining specks and fragments of vegetable matter, but on exposure it bleaches to a grey, pale buff, or almost white rock; in the Guryul ravine, however, this band is only a few inches thick, whereas on the Risin spur the thickness is very considerable.

Chert bands.

The cherts, which are most conspicuous on both sections, are also very characteristic rocks: at Risin they are almost invariably black and are intimately associated with dark crystalline limestone, the two rocks alternating and passing into one another not only vertically, but also along the strike; bands and lenticular patches of the limestone run through

the chert, the one rock appearing in the field to pass insensibly into the other. In the Guryul ravine, on the other hand, limestone is practically absent; a few patches of very impure calcareous material in bed No. 4 being the only apparent representatives of the well-defined limestones of Risin. Here, however, chert is very much more abundant and more variable both in colour and in texture, ranging from a black velvety rock to a creamy white variety, exactly like "Arkansas stone,"[1] the typical form of novaculite.

Fossil plants on Guryul section.

The presence of cherts in both sections first led to a careful search for *Gangamopteris* in the Guryul ravine, but it was only after an exhaustive examination of every layer on the section described above that a frond was at last found in the intensely hard siliceous band associated with the carbonaceous shales (bed No. 5); a few more fragmentary specimens were obtained from the same layer, but all are very poorly preserved and the evidence seemed hardly conclusive.

Zewan section.

A visit to the Zewan section (Pl. 7), near Panduchak, however, removed all doubts and completely established the position of the Gangamopteris horizon. This section is already familiar from the work of Godwin-Austen,[2] Verchere,[3] and, recently, of Mr. Oldham. Here a complete sequence is found ranging from the trap up to the shales and limestones with marine fossils, named by Godwin-Austen the "Zewan beds." The beds dip at high angles (50°—60°) to east-south-east. Near the base of the section Mr. Oldham found a bed of carbonaceous shale exactly like that in which *Gangamopteris* occurs on the Risin spur. I was fortunate enough to be able to confirm the identity of these two beds, since at Zewan I found specimens of *Gangamopteris* similar to those of Risin. Above the carbonaceous shales there appears to be a perfectly conformable sequence up to the fossiliferous Zewan beds.

Along the crest of the ridge, the trap is immediately overlain by a white chalcedonic rock, like that of the basal bed in the Guryul ravine and identical with novaculite: from this a section (Pl. 4, fig. 2)

[1] I am indebted to Mr. T. R. Blyth, Assistant Curator, Geological Survey of India, for drawing my attention to the remarkable resemblance between the two rocks.

[2] *Quart. Journ. Geol. Soc.*, XXII, 33 (1866).

[3] *Journ. As. Soc. Bengal*, XXXV, No. 2, 129 (1867).

was measured up to the shales with marine fossils (Zewan stage) : it is as follows :—

Zewan beds.	23. Shale with *Protoretepora ampla, Lyttonia* and brachiopods	...
	22. Cherty band with *Productus cora* d'Orb.	4 ft.
Gangamopteris series.	20. Dark grit	3 ins.
	19. Shale, calcareous and earthy	4 ft.
	18. White and green chert	1 „
	17. Shaly siliceous grit	4 „
	16. Chert and fine-grained quartzite	50 „
	15. Shale in 1 ft.—3 ft. beds, with thin limestone bands. .	18 „
	14. Thin-bedded limestone, with some shale at the base .	15 „
	13. Hard siliceous shale, slightly carbonaceous at the top and containing a few fragments of plants	12 „
	12. Carbonaceous shale	4 „
	11. Shale and thin-bedded limestone	25 „
	10. Shale like 8, with thin (2"—3") pebble band at base .	4 „
	9. Somewhat concretionary limestone, with occasional shale bands	2 „
	8. Shaly pebble bed : pebbles large (up to 5" in diameter) in lower part and small in upper	3 „
	7. Flaggy siliceous-bed with bands of small pebbles . .	1 „
	6. Siliceous shale or chert	10 „
	5. Limestone	4 „
	4. Siliceous shale or chert	7 „
	3. Carbonaceous shale with *Gangamopteris*	3 „
	2. Siliceous shale	20 „
	1. White novaculite	25—30 „ (variable).

Gangamopteris at Zewan.

The most important feature of the section is naturally the presence of *Gangamopteris* in the carbonaceous shales. The fossils are extremely rare and the few found were only obtained after prolonged search : they are best seen on the weathered surface of the shale. I found no traces of either *Amblypterus* or *Archegosaurus*, but the few hours at my disposal were quite insufficient for a thorough exploration of the bed. Circumstances unfortunately precluded a longer stay and it was impossible to do more than measure and examine the rest of the section in a most cursory manner, but a few observations were made which seem to throw some light on the relationship of the volcanic beds to the overlying rocks.

Novaculite.

The first of these relates to the basal bed, the novaculite,[1] as seen on the crest of the spur. This rock has been described variously as a compact quartzite (Godwin-Austen) and a bed of quartz (Oldham), but in both macroscopic and microscopic characters it agrees entirely with a specimen of "Arkansas stone" included among the collections in the Geological Museum in Calcutta. On the Zewan section it forms a thick bed on the crest of the spur and is immediately overlain by siliceous shale, the chert and limestone which is seen at the base of the Risin section being apparently absent. If, however, the novaculite bed is followed towards the west, it is found to thin out rather rapidly to a thickness of only six or seven feet and then to dwindle away to nothing. As the novaculite thins out, its place is taken by crystalline limestone and chert, and at the end of the outcrop nearest to Panduchak the sequence is similar to that at Risin. The presence of the novaculite on some sections and its absence from others was drawn attention to by Mr. Oldham and was possibly one of the causes that led him to assume that the junction between the trap and the overlying beds was an unconformable one; others were the abrupt cessation of volcanic rocks at one particular horizon and the remarkable variation in the respective sections.

Origin of the cherts and novaculites.

The capricious distribution of the novaculite is at first sight puzzling, but a study of the sections shows that where it is present the lowest limestones are absent or only imperfectly represented. The section at Zewan includes both rocks, the novaculite being at one end of the outcrop and the limestone at the other, while the interval between the two is occupied by both rocks but in reduced thickness; it is impossible to resist the conclusion that the novaculite has originated in the metasomatic replacement of the limestone by silica. Such an origin was suggested some years ago by Mr. F. Rutley for the Arkansas novaculite,[2] and his theory is entirely borne out by the Kashmir rocks.

Under the microscope, their history can be followed with wonderful clearness, and a perfect passage traced from an almost pure limestone into a black chert and thence into typical novaculite.

The original condition of the rock was an oolitic limestone (see Pl. 8, fig. 1); this subsequently became crystalline on a coarse scale,

[1] If this rock can be found free from joints, it should be valuable as a whet-stone.
[2] *Quart. Journ. Geol. Soc.*, Vol. L, 377 (1894).

for many adjacent calcite grains as well as the intervening ground-mass show the same orientation over very considerable areas. Under the microscope, this is clearly seen in the simultaneous extinction of large areas and in the extension of the twin-lamellæ of the calcite from grain to grain across the ground-mass (fig. 2), while in the hand specimen the effect is a very striking " lustre-mottling."

The next stage was the gradual replacement of the calcite by chalcedonic silica to form a black chert; the ground-mass was first attacked, and the process can be traced in every stage through a rock composed of grains of calcite imbedded in a matrix of chalcedony (Pl. 9, fig. 3) to the final chert composed of oolitic grains of silica in a matrix of the same material (Pl. 8, figs. 3 and 4).

The dark colour of the limestone and of the resultant chert appears to be chiefly due to carbonaceous matter, but also to the presence of some fine mud and a little manganese oxide.[1]

These dark materials originally either occupied the centre of the grains of oolite or were deposited in rings during their formation: both conditions can be seen in the limestone. When crystallisation set in, either the original conditions survived or in some cases the dirt was exuded towards the outer surface and is now seen as a dark ring round the grains or is occasionally noticed along the cleavage cracks of the calcite.

The evidence furnished by the microscope leaves no doubt as to the inorganic origin of these cherts, for they not only retain perfectly the oolitic structure of the original limestone, but every stage in the replacement of the calcite by silica can be traced. Nor is the silicification confined to the limestones, but has extended to the associated shales and sandstones, and in the Guryul section the carbonaceous shale with plant remains has been converted into a hard hornstone breaking with conchoidal fracture. At the same time the negative evidence implied in the absence of recognisable sponge spicules or other siliceous organisms further supports the above view. The mode of origin of the oolitic grains is uncertain, and may have been either organic or inorganic, but certain structures visible under the microscope are suggestive of the tests of foraminifera, such as *Endothyra*, while several plant fragments can be clearly recognised as nuclei of the grains.

[1] The limestone contains alumina and gives a decided reaction for manganese.

Silicification due to solfataric action.

As will be seen below (p. 36), there is no reason for supposing that there was any great time interval between the occurrence of the last lava-flow and the deposition of the carbonaceous limestones; the cherts and novaculites may consequently be regarded as products of the final or solfataric phase of the volcanic activity. The novaculite differs from the chert chiefly in colour and in the almost complete obliteration of the oolitic structure, but even here intermediate stages can be found, for some specimens have a distinct granular structure and contain occasional patches and strings of dirt; as a rule, however, the rock is bluish, greenish, or creamy white, and free from the carbonaceous matter to which the chert and limestone owe their colour; and it may be regarded as a bleached chert, which might have been produced by the action of heat on the carbonaceous rock, having thus been formed in the immediate neighbourhood of fissures in the underlying trap. Solfataric action would not only suffice to explain the silicification of the limestones, but would also account for the local substitution of novaculite for chert.

The period during which this silicification occurred can be defined with considerable nicety, for it has nowhere been found to extend as high as the beds with *Protoretepora ampla*, which occur near the base of the fossiliferous Zewan beds (bed 7 in the Guryul ravine and bed 23 on the Zewan section). It must, therefore, have taken place after the solidification of the last trap-flow and before the deposition of the beds with *Protoretepora ampla*: that it began at an early part of this period would appear from the fact that pebbles of a chert exactly like that of the main band at the base of the series occur in a pebble-bed (bed 8) low down in the section at Zewan; if the two rocks be the same, the chert must have been formed and locally denuded at an early stage. Not only cherts, however, but silicified shales and sandstones occur again higher up in the same section (bed 16), while in the Guryul ravine chert bands occur throughout the whole section between the trap and the Zewan beds; it is evident, therefore, that silicification occurred more or less throughout the whole period during which the beds of the Ganmopteris series were beingdeposited. This lends further support to the view that it represents the solfataric stage of this volcanic period.

Local variation of Gangamopteris series and Zewan beds.

Much of the variation to which attention has been drawn by Mr. Oldham can thus be explained by local alteration of the component beds on the respective sections, but this does not account for such evident

difference of character of the original sediments as is readily apparent from a comparison of a section such as that of Zewan with those of Mandakpal and Rechpura on the eastern side of the Vihi plain. At Zewan the beds between the trap and the base of the Zewan beds are over 200 feet thick and include littoral deposits (pebble-beds, sands, etc.), whereas at Mandakpal they consist of a considerable thickness of dark ferruginous shale, capped by a band (5 feet thick) of greenish and bluish chalcedony. At Rechpura, according to Mr. Oldham, the lowest limestones of the Zewan stage lie directly on the volcanic beds. Although this variation does not necessarily imply unconformity, since the shore deposits of Zewan might well be represented by shale and limestone at a locality ten miles distant, yet it is not unnatural to expect that local disturbances occurred during a period of such marked volcanic activity; but if any unconformity does exist, it does not necessarily involve any great time interval: this has already been pointed out by Mr. Oldham, and since none of the usual direct evidences of unconformity—such as discordance, erosion of the trap, the presence of conglomerates, etc.—are found on the section at Zewan, there is no reason to suppose that there was any serious interruption of continuity between the outpouring of the last lava-flow and the deposition of the Gangamopteris series.

With regard to the question of a possible unconformity above the Gangamopteris beds, I have seen only a few of the many sections to be found in and around the Vihi plain and am consequently not in a position to deal with this adequately. So far as I could see there is no evidence of any break between the Gangamopteris beds and the Zewan stage either at Zewan or in the Guryul ravine. On the former section the presence of pebble-beds and carbonaceous shales with remains of land plants is suggestive of either coastal or estuarine conditions, and the pebble-beds may undoubtedly be taken to indicate a certain amount of contemporaneous erosion due to local oscillations of the coast-line.

In the Guryul ravine the Gangamopteris series is thinner than at Zewan and more completely silicified, but the carbonaceous shales (bed 5, *supra*, p. 26) are exactly like those of Risin and Zewan, and furthermore contain fragments of plants, which, though very badly preserved, are, I think, referable to *Gangamopteris*. If, therefore, we find such marked lithological variation in the space of about three miles—the distance of the Guryul ravine from Zewan—we should

naturally expect even greater variation at more distant localities, such as Mandakpal and Rechpura, which were probably some way from the coast-line as defined by the Gangamopteris beds, and it would not be surprising to find the shallow-water deposits of the one area represented by limestones in the other.

At Zewan the Gangamopteris series is overlain first by a thin band of somewhat siliceous limestone containing *Productus cora* d'Orb.; above this is a considerable thickness of black shale full of beautiful specimens of *Bryozoa*, the most conspicuous of which is *Protoretepora ampla* Lonsd.; above this again is a limestone containing a variety of fossils, chiefly brachiopods. Wherever beds of the Zewan stage were seen by me, the horizon of *Protoretepora ampla* was always recognised immediately by the excellence and profusion of this characteristic fossil. At Zewan it is apparently restricted to shale; in the Guryul ravine it is found partly in a thin bed of shale and partly in limestone; on a ridge to the south-west of Mandakpal, it is found chiefly in shale, whereas to the east-south-east of the same village the rock in which it occurs is almost exclusively a limestone; thus we have the same horizon represented in one place by shale, in another by limestone, and in a third partly by both; this is of course only what might be expected, and is, I think, sufficient to justify us in considering the case for unconformity above the Gangamopteris series not fully established. We thus have evidence that the Gangamopteris series is older, but, if we assume that there is no unconformity, only slightly older, than the Zewan stage.

The Zewan stage.

The Zewan stage (*sensu stricto*), as defined by Godwin-Austen, includes only the fossiliferous shales and limestones capping the section at Zewan, but has generally been taken to comprise the fossiliferous series with *Bryozoa* and brachiopods as seen in part at Zewan, and more completely in the Guryul ravine and at other localities around the Vihi plain,[1] and so to include all the beds between the Gangamopteris series and the lower Trias. The presence of the latter stage had not been detected at Khunmu, where it was supposed by Dr. Noetling that the upper Trias was faulted against the Zewan beds. This view is represented in the diagram published by Dr. Noetling in his paper already referred to.[2]

[1] R. Lydekker: *Mem. Geol. Surv. Ind.*, XXII, 132 (1883).
[2] *Op. cit.*, p. 130, fig. 1.

I was unfortunately unable to devote any time to this section, but traversed it rapidly at two or three points on the left side of the Guryul ravine. All the beds above the Gangamopteris series are shales and limestones, and consist roughly of limestone with subordinate shales below, followed by shale with subordinate limestones, and these again, capped by a thick series of limestone forming steep cliffs. The lowest group of beds comprises the horizon of *Protoretepora ampla*, followed by several brachiopod-bearing horizons, characterised chiefly by the genera *Athyris* and *Productus*: the next group consists chiefly of shale below with alternating beds of shale and limestone (in beds of from 6 inches to 1 foot in thickness) above. This second group is very well exposed on the small spur ending in the cliff overhanging the chenar trees at the mouth of the Guryul ravine where it forms the saddle running from the top of the cliff to the foot of the next limestone cliff to the east (Pl. 6). Further up the ravine these lower beds, which are largely composed of shale, contain fossils, collected in small patches which evidently represent hollows in the old sea-floor; the fossils are chiefly *Marginifera himalayensis* Diener and are characteristic of the Productus shales in other parts of the Himalaya. At about 10 feet above this horizon is a band of dark shale weathering white and not unlike the carbonaceous shales of the Gangamopteris series: it does not, however, contain plant remains, but yielded a few specimens of *Pseudomonotis* sp. cf. *Griesbachi* Bittner. Immediately above this is a thin band of very hard limestone with species of *Danubites*, *Flemingites*, and *Bellerophon*. This is followed by rapidly alternating beds of similar hard limestone and shale: the whole sequence bears a striking lithological resemblance to the lower Trias of Spiti and the fossils at the base leave no doubt as to its identity. The third group, which is composed of hard limestone in beds of about 2 feet thick, and forms a conspicuous line of cliffs on the left side of the valley, probably represents the nodular limestone and the muschelkalk of Spiti, but I had no time to search for fossils which appear to be very rare.

Section in Guryul ravine.

Productus shales.

Lower Trias of Guryul.

The above is only a very broad classification of the beds above the Gangamopteris series, but it is sufficient to prove the presence in the Guryul ravine of at least three well-marked stages,—a calcareous series below, with *Bryozoa* near the base and *Athyris* above, a (mainly

shaly) series in the middle, with *Marginifera himalayensis*, and an alternating series of shale and thin-bedded limestone containing fossils of lower Triassic age.

Mandakpal: Productus shales.

Turning now to Mandakpal at the other side of the Vihi plain, the sequence exposed on the ridge to the east-south-east of the village, from the base of the Zewan stage upwards, is very similar, with the exception that all the beds are rather more calcareous. In the middle shaly series two highly fossiliferous bands are well exposed; the lower is a continuous bed, several inches thick and is almost entirely made up of *Marginifera himalayensis* Diener and other brachiopods. A little higher in the section, a calcareous bed, about six inches thick, is equally rich in specimens of *Spirifer rajah* Salter and other species of *Spirifer*.[1] There can, I think, be no doubt that these shales, with *Marginifera* and *Spirifer* at Mandakpal and *Marginifera* in the Guryul ravine, represent the Productus shales of Spiti and the rest of the Himalaya, differing from them only in being locally rather more calcareous; they are, however, often micaceous and are then exactly like the Productus shales of Spiti.

Age of Zewan stage.

Some years ago, before I had had an opportunity of seeing the Zewan beds, I suggested that they were probably the equivalent of the Fenestella shales of Spiti;[2] in this Dr. Diener agreed with me,[3] and I am now convinced that our view was on the whole correct, although it will require some modification if we include in the term Zewan stage all the beds between the Gangamopteris series and the lower Trias: in that case the Fenestella shales will be represented by the lower beds with *Protoretepora ampla* and other *Bryozoa*, and the Athyris limestones of Vihi may be the equivalent of the calcareous sandstone of Spiti.

Age of the Gangamopteris series.

It has now been definitely ascertained that the Gangamopteris beds overlie the trap and underlie the Zewan beds: their age consequently depends on that adopted for the latter stage. This is usually regarded as upper Carboniferous, but it has now been shown that the Zewan beds include the Productus shales, which are admittedly of

[1] These are evidently the bands referred to by Lydekker: *op. cit.*, p. 134.
[2] *Gen. Rep. Geol. Surv. Ind.*, *1899-1900*, p. 189.
[3] C. Diener: *Pal. Ind.*, Ser., XV, I, pt. 2, p. 199.

Permian age: if the term "Zewan stage" is to be retained, it should be rigidly restricted to the horizons exposed at Zewan and originally so named by Godwin-Austen; the lower of these includes beds 22 and 23 (*sùpra*, p. 28) of which bed 23 is almost certainly the equivalent of the Fenestella shales of Spiti, and consequently of upper Carboniferous age. Bed 22 is only of inconsiderable thickness, but contains immense numbers of *Productus cora* d'Orb. and may thus be homotaxial with the Cora horizon of the Ural and Timan mountains. Such a correlation is borne out by the fact that the overlying bed (23) contains *Lyttonia* and may therefore be homotaxial with the *Lyttonia*-bearing beds of Loping in China which have been referred by Professor Tschernyschew to the Schwagerina horizon of the Urals.[1] This, however, is merely offered as a tentative suggestion, since no close or systematic study has ever been made of the upper Palæozoic horizons of Kashmir in the light of recent stratigraphical discoveries; it is highly desirable that this should be done since the results will certainly help to elucidate the relationship of the Carboniferous deposits of the Central Himalaya and the Salt Range to those of Eastern Europe. All we can say at present is that the Gangamopteris beds are not younger than upper Carboniferous and may belong to the base of that sub-division or even to the middle Carboniferous. The lower limit of age can only be decided by determining the age of the trap. This will be a matter of great difficulty, but some light will probably be thrown on the question by a section recently observed at Imselwara (or Ambersilwara) near Harwan, in the hills to the N.N.E. of Baramula. Here I found a series of limestones, probably between two and three hundred feet thick, interbedded with the trap.[2] Fossils are numerous, but very poorly preserved; they include species of *Spirifer*, corals, and crinoids. The limestones are quite unlike those of the Zewan stage and are probably much older: I was unfortunately unable to stop to examine them, but it is probable that further search would result in the discovery of determinable fossils and go far towards establishing the age of the trap.

Imselwara limestone.

[1] Th. Tschernyschew: Die ober-carbonischen Brachiopoden des Ural und des Timan. *Mem. Com. Geol.*, XVI, No. 2, St. Petersburg (1902), p. 729. (A translation of parts of this paper has been published in *Rec. Geol. Surv. Ind.*, XXXI, pt. 3.)

[2] The cave containing pleistocene fossils, and recently discovered by Messrs. Radcliffe and Campbell, is in this limestone: see *Indian Forester*, Vol. XXXII, No. 6, 313 (1906).

The presence of this limestone apparently interbedded with the trap is also of interest as supporting the view usually adopted that the latter rock consists of actual lava-flows—possibly sub-aqueous—and is not of intrusive origin. The clearly amygdaloidal character of many of the beds and the apparent absence of apophyses from among the overlying sedimentary rocks is further evidence in support of this view. The only feature which can be regarded as pointing to a possible intrusive origin is the curious manner in which the overlying fossiliferous sedimentary beds—to use Verchère's expression—"lap round" the igneous mass. This character is noticeable on both sides of the Vihi plain, and is especially well-marked in the neighbourhood of Khunmu, where, as will be seen from the sketch-map, the dip of the sedimentary beds, which in the Guryul ravine is towards the east, gradually bends to S.E. and E.S.E. at Risin. Bedding and dip in the underlying trap is not always clear, but so far as it can be traced seems to follow exactly the same course as in the overlying beds, and the Zebanwan hill-mass appears therefore to be a dome rather than a laccolite. The dome-like forms of both the Zebanwan mass and of Wastarwan may, however, be quite possibly due to local uplifts consequent on movements in the molten material which might naturally be supposed to have existed beneath these great masses of igneous material, thus producing a broad trough now represented by the Vihi plain.

Origin of the trap.

The fact that the Gangamopteris beds have been definitely ascertained to be older than the Protoretepora horizon of the Zewan beds has a further and important bearing on the geology of Spiti, and incidentally on the vexed question of the correlation of the Blaini boulder-bed of the Simla hills.

Representatives of Zewan stage in Spiti.

It has already been pointed out that the Protoretepora horizon of Kashmir is the exact counterpart of the Fenestella shales of Spiti, and the beds between the base of the Zewan stage and the lower Trias in Vihi must therefore be the equivalent of the series extending in Spiti from the base of the Fenestella shales to the Otoceras zone, thus including the conglomerates which underlie the calcareous sandstone at and around Po. The absence of any break between the Zewan stage and the lower Trias in Vihi thus proves that the great Palæozoic unconformity, which has hitherto been regarded as the most marked and persistent feature in Himalayan geology,[1] did not

[1] *Mem. Geol. Surv. Ind.*, XXXVI, p. 51 (1904).

extend into the valley of Kashmir, and if we are right in regarding the Gangamopteris series of Khunmu as the equivalent of the lower Gondwanas of India, it is evident that the conglomerate of Spiti cannot represent the Talchir boulder-bed, but must be much younger, and the last remaining reason for regarding it as of glacial origin and correlating it with the Blaini boulder-bed of Simla now disappears.

Summary.

The Gangamopteris beds of Vihi have been found at Zewan in an apparently continuous section, underlain by trap and overlain by the Zewan stage, which is the equivalent of the Fenestella shales of Spiti. Their age is therefore certainly not younger than upper Carboniferous.

The series is everywhere characterised by the occurrence of chert and, locally, of novaculite, which have been derived from pre-existing limestone by the metasomatic replacement of the carbonate of lime by silica, with perfect preservation of the structure of the original rock. This probably indicates the solfataric stage of the later Palæozoic volcanic period of Kashmir.

The beds at the base of the Zewan stage are highly fossiliferous and are especially characterised by the presence of *Protoretepora ampla* Lonsd.

Above this horizon are limestones containing brachiopods and overlain by shales with fossils characteristic of the Productus shales of other parts of the Himalaya. These are overlain, in the Guryul ravine, by beds with lower Triassic fossils.

The sequence from the base of the Zewan stage up to the Trias is complete and conformable, and there are no signs of the great upper Palæozoic unconformity so universal in the Himalaya.

EXPLANATION OF PLATES.

PLATE 5—

1 = *Gangamopteris* beds of Risin spur.
2 = Zewan stage.
3 = *Productus* shales and Lower Trias.
4 = Muschelkalk (?).

PLATE 7—

1 = Novaculite.
2 = *Gangamopteris* horizon.
3 = Zewan stage.

PLATE 8—

Fig. 1. Oolitic limestone, Risin spur near Khunmu.

" 2. The same under crossed nicols, showing twinning lamellæ of calcite running through grains and ground-mass. The whole field is part of a single crystal of calcite.

" 3. Black chert. The whole rock has been silicified, but retains its original structure.

" 4. The same under crossed nicols.

PLATE 9—

Fig. 1. White novaculite from base of section in Guryul ravine, near Khunmu granular structure still apparent, but not so pronounced as in the black chert (Pl. 8, fig. 3).

" 2. The same under crossed nicols.

" 3. The same rock as Pl. 8, fig. 1, partially changed to chert. Grains of calcite with ragged, corroded edges are seen lying in a matrix of chalcedony, derived by replacement of the calcareous ground-mass by silica, nicols crossed.

" 4. Chalcedony (translucent form of the novaculite) from Mandakpal. Nicols crossed.

ON A VOLCANIC OUTBURST OF LATE TERTIARY AGE IN SOUTH HSENWI, NORTHERN SHAN STATES. BY T. H. D. LA TOUCHE, B.A., F.G.S., *Superintendent, Geological Survey of India.* (With Plates 10 and 11.)

IT is somewhat surprising that in the Northern Shan States, where a fairly complete series of Palæozoic and Mesozoic rocks (with the exception of Cretaceous) has been found, not a single instance of the intrusion of igneous rocks has been discovered in any formation of later age than the Cambrian. The whole of the lapse of time represented by the accumulation of the fossiliferous rocks of the Shan plateau appears to have been one of complete volcanic quiescence, and even beyond the limits of the Shan hills the same conditions seem to have prevailed; for if we except the andesitic intrusions of Wuntho and the serpentines of the Arakan Yoma, the age of which is not precisely known, all the basic igneous rocks of Burma are of Tertiary age.

It is not easy to account for this complete absence of volcanic activity throughout so long a period, for it is certain that considerable earth movements took place from time to time during the accumulation of the stratified deposits; but the explanation probably is that these movements were mainly of a tangential character, resulting in the folding and squeezing together of the strata, and that it was not until Tertiary times that the great dislocations or faults, which are more likely to be accompanied by manifestations of volcanic activity, began to be developed.

During a rapid traverse through the South Hsenwi State early in 1905, the writer found near the village of Man-Sang (22° 26′ : 97° 58′), where there is a large patch of Tertiary silts and sands with seams of coal, numerous traces of the existence in the neighbourhood of basic igneous rocks, many of the watercourses being choked with loose blocks of basalt, but want of time prevented his following the matter up. Mr. R. R. Simpson also, in the course of his examination of

the Man-Sang coal-field, came upon the same rocks,[1] and was of opinion that they were either intrusive in the Tertiary silts, or that the latter had been laid down upon an irregular surface of the basalts. On a second traverse made during the field season of 1905-06, I made a point of visiting the principal exposures of these rocks marked by Mr. Simpson, and spent a couple of days in examining their features.

The igneous outburst which forms the subject of the present paper occurs in a small conical knoll called Loi Han Hun, rising to 3,610 feet above sea-level, and situated about two miles south-west of the village of Nawng-tao (22° 30′: 98° 1′), on the cart-road between Lashio and Mong Yai, the capital of South Hsenwi State. Coming up from the south-east, from the direction of Mong Yai, the hill catches the eye at once by reason of its conical or rather dome-shaped appearance, differing as it does greatly from that of the low undulating mound-like hills formed of the soft Tertiary rocks, which cover the surrounding country. The hill rises to a height of about 700 feet above the general level, whereas the other elevations in the neighbourhood, with the exception of the hill ranges to the north, do not rise to more than 200 or 300 feet. It is, however, apparent at once that it is only the upper part of the hill, which is very steep on all sides, and forms a regular dome, that has a distinctive appearance, for the lower, more gently sloping portion differs in no way from any of the surrounding mound-like elevations. An examination of the structure of the hill at once discloses the cause of this peculiar shape. On searching among the ravines that drain the lower portion of the hill, I found that this is composed of the soft Tertiary silts and sand-rock, among which was a band of carbonaceous clay, a representative of one of the coaly layers that are known to occur in this formation. These beds are nearly horizontal, but have a very slight dip towards the south-east. They are so soft, and the stream beds are so choked with débris from the igneous rocks higher up the hill, that it is by no means easy to find an outcrop of them. Proceeding further up the slope, dykes of hard basalt, radiating in all directions from the central dome, make their appearance on the spurs, some of them extending to considerable distances. Each of the dykes exhibits a well-defined columnar jointing, the columns being horizontal, and their

[1] *Rec. Geol. Surv. Ind.*, XXXIII, p. 141.

polygonal ends appearing on the vertical outer walls of the dykes, which stand out boldly from the surrounding slopes (Pl. 10). I made an attempt to discover whether the rocks in contact had been altered in any way by the intrusion, by digging pits alongside two of the dykes, but the results were not satisfactory. Although the surface soil was perfectly dry, I found that, at a depth of only 2 or 3 feet from the surface, there was a copious discharge of water from the dykes, and the rock in contact with them was a stiff blue clay, which showed no signs of induration or other alteration. There can be no doubt, however, that the dykes are really intrusive.

The central dome-like mass forming the upper part of the hill is built up of dykes and bosses of columnar basalt, in which the columns may be found inclined at all angles to the horizon (Pl. 11). The surface of some of these bosses has a curiously rounded or mammillated appearance, as though the molten rock had been forced up a fissure, and cooled under pressure before it quite reached the surface. In fact, the whole mass bears more resemblance to a *laccolite,* than to a true volcanic pipe or neck. There are slight traces of amygdaloid and vesicular structure in the upper part of the mass, but no signs of actual flows of lava in connection with it, nor could I find any such in the immediate vicinity of the hill. The remains of true flows may be found when the country to the west and north-west is more thoroughly examined, for Mr. Simpson mentions the occurrence of amygdaloid lavas in that direction, but these may have proceeded from a separate orifice, the position of which has not yet been located. It is possible, of course, that the present dome of Loi Han Hun represents only the lower portion of a volcanic neck, the upper, more vesicular portion of which has been removed by denudation; but the mammillated appearance of the bosses seen on the summit of the hill seems to indicate that this was the original surface of the basalt, and the Tertiary rocks through which it is protruded belong to such a very late period that I think it hardly possible that every trace of the upper portion of the plug, if it ever existed, should have disappeared.

The rock of which the dykes and central dome are composed is a dense fine-grained basalt, almost black in colour with a greenish tinge. The specific gravity is 2·941. Under the microscope the ground-mass is seen to consist of minute lath-shaped crystals of plagioclase felspar and minute greenish-yellow granules of augite, which sometimes form aggregates arranged in a roughly radial manner, also

abundant magnetite. Larger crystals of plagioclase, with zonal inclusions of the ground-mass, and granular crystals of olivine, sometimes fissured and partly converted into serpentine, are imbedded in the ground-mass.

This rock differs from that of the Tertiary basalt flows of Shwemyindé hill, opposite Kyaukmyaung on the Irrawadi, about 40 miles above Mandalay, in that the augite in the latter is of a pinkish-brown colour, probably owing to the presence of titaniferous iron-ore, and is not so abundant. Otherwise the constituents of the rock are the same, but there is rather more olivine and much more felspar in the Shwemyindé rock. This has a specific gravity of only 2·699, but its want of density may be partly due to the presence of minute gas pores.

A basalt from the extinct volcano Hawshuenshan (Hoschuen-shan) near Teng-yueh (Momien), in south-west Yunnan, which may be of much the same age as that of Loi Han Hun, is described by Professor v. Lóczy in Graf Bela Szechenyi's *Reise in Ostasien* (Vol. III, p. 379). The rock is described microscopically as consisting of microlites of plagioclase felspar (andesine), imbedded in a glassy paste filled with yellowish or greenish granules of augite and crystals of magnetite. Larger crystals of felspar with zonal inclusions of the ground-mass, and crystals and granules of olivine, much fissured, are scattered through the slide. This rock therefore resembles the basalt of Loi Han Hun very closely in composition, except that the latter contains no glass. Indications of the former existence of a glassy basis are, however, seen in a specimen of amygdaloid basalt collected by Mr. Simpson at Namaklang, about two miles west of Loi Han Hun, probably from a lava-flow.

The older portion of the volcano of Hawshuenshan consists of augite-andesite (*Reise in Ostasien*, Vol. I, p. 771), but no traces of this rock have been found in the Shan States. The lava of the ancient volcano Popa or Puppa, in the Myingyan district, also of upper Tertiary age, is, however, mainly, if not entirely, augite-andesite, and if the relations of the rocks at Hawshuenshan are any guide, it would appear that the basalts belong to a later date of eruption than the andesites, and that the basalts of Loi Han Hun belong to quite a recent period. The Tertiary silts into which they are intruded must represent quite the highest deposits of that era, for they have evidently been accumulated since the principal drainage features of the plateau

were marked out, and the shells they contain are all of very recent fresh-water types, such as *Paludina* and *Planorbis*.

EXPLANATION OF PLATES.

PLATE 10.—Basalt dyke, intrusive in Tertiary rocks, on north side of Loi Han Hun, showing horizontal columnar structure.

PLATE 11.—Columnar basalt, summit of Loi Han Hun, showing inclined position of columns.

DESCRIPTION OF SOME NEW SUIDÆ FROM THE BUGTI HILLS, BALUCHISTAN. BY GUY E. PILGRIM, B.SC., F.G.S., *Geological Survey of India.* (With Plate 12.)

SOME months ago a small collection of vertebrate remains, obtained from the hills 25 miles N.E. of Dera Bugti, was sent down to Calcutta by Major A. McConaghey, I.A., Superintendent of Imperial and District Gazetteers, Baluchistan, and was put into my hands for examination. These fossils proved no less interesting than those collected by Blanford during his brief stay in the Bugti hills and described by Lydekker in the Palæontologia Indica. The former collection yielded several new forms to Lydekker's examination, and the same is the case with the present find.

Amongst the fossils which I have had under examination are two left upper molars and a canine of a new species of *Anthracotherium* of large size and allied to the various large European forms; an upper molar, which is intermediate in character between the two groups of the Anthracotheriidæ and Merycopotamidæ and whose peculiar characters indicate it as a new genus; a mandible representing a new species, which is possibly the same as the last mentioned upper molar; and the front part of a skull containing portions of the maxilla and premaxilla, but of which the tooth crowns have been completely worn away. Its affinities are somewhat obscure, though it is probably Suine. In any case, however, it shows a structure and type of dentition which is unique. The specimen is not described or figured on account of its fragmentary condition. I hope, however, at no very distant time, to have further material in my hands, which may elucidate its structure. Besides these occur several molar teeth and mandibles of *Aceratherium blanfordi* Lyd. and *Aceratherium perimense* Falc. et Caut.

The following is a list of the vertebrate species which we at present know to occur in these beds:—

Mastodon (*Tetrabelodon*) *angustidens* Cuv. *var. palæindicus* Lyd.

Mastodon (*Tetrabelodon*) *pandionis* Lyd.

Mastodon (*Tetrabelodon*) *falconeri* Lyd.

Anthracotherium hyopotamoides Lyd.
Anthracotherium nov. sp. aff. magnum.
Brachyodus giganteus Lyd.
Nov. genus, nov. sp.
Aceratherium blanfordi Lyd.
Aceratherium perimense Falc. et Caut.

Our only information on these beds is due to Blanford's brief visit. He classed them with the lower Manchhars, and therefore considered them as forming the base of the great continuous series of the Siwaliks. Consequently they have very generally been spoken of as pliocene, and the oldest age that has been assigned to them is upper miocene, still regarding them as lower Siwaliks. Their vertebrate fauna is, however, of a character distinctive of the lower miocene or even of an older epoch. The invertebrate fauna points no less in the same direction; out of seven species of freshwater mollusca, which Blanford[1] described from these beds, only one presented any close affinities with recent forms. In this novelty of facies the freshwater mollusca are in striking contrast to those of the upper Siwaliks, in which the species are all living at the present day.

Although Blanford seems finally to have decided that the Bugti beds were lower Siwalik, another possibility had occurred to him. Struck by the absence of the Gaj Series in this area, and perhaps by the fact that there is no apparent unconformity between the Bugti beds and the underlying formations, he suggested[2] that the bone beds might possibly represent a local facies of the Gaj.

This has again been suggested more strongly by my colleague Mr. E. Vredenburg,[3] who remarks on the invariable unconformity between the true Siwaliks and the underlying formations.

If then the Bugti beds represent the Gaj series, they must certainly be placed at the base of the miocene,—the position to which their fauna, both vertebrate and invertebrate, would incline us to assign them.

It is to be hoped, however, that a stratigraphical examination of the ground will before long settle the point definitely.

[1] W. T. Blanford. Hills from Quetta to Dera Ghazi Khan. *Mem. Geol. Surv. Ind.*. XX, pp. 162 and 233 (1883).
[2] W. T. Blanford, *ibid.*, p. 160, footnote.
[3] *Rec. Geol. Surv. Ind.*, XXXIV, p. 92 (1906), footnote.

With this introduction I shall now proceed to the detailed description of the new species. I wish here to express my thanks to Dr. A. Smith Woodward, F.R.S., the Keeper of the Geological Department of the British Museum, for his kindness in placing at my disposal all the British Museum specimens, to which I have wanted to refer, and to Dr. C. W. Andrews, F.R.S., for much kindly help and suggestion during my work. To Miss G. M. Woodward I am indebted for her careful drawings of the specimens.

SUINA SELENODONTIA.

PENTACUSPIDATI.

ANTHRACOTHERIIDÆ.

Genus—ANTHRACOTHERIUM.

Species—ANTHRACOTHERIUM BUGTIENSE nov. sp.

Amongst the remains from Dera Bugti, which have come into my hands, are the two last left upper molars and a canine of a large species of *Anthracotherium*. The two molars are almost unworn, and are in a good state of preservation. The last molar lacks only the summit of the metacone, which has been broken off. Lydekker[1] figured a fragment of a mandible obtained by Blanford from the same or somewhat the same locality, which he referred provsionally to *Anthracotherium magnum* Cuv. It is at least likely, however, that it belongs to the same species as the two upper molars figured in Pl. 12, fig. 1, and to which I have no option but to assign a distinct specific name. The differences between the various European species of *Anthracotherium*, more especially in regard to the structure of their upper molars, is so slight that it is necessary to insist on the various small distinctions between the present tooth and the corresponding teeth of all other specimens which have been described and figured. These forms have not always even received distinct specific names, but have been referred to by the locality, where they were found. Most of them are at present included under the name

[1] *Pal. Ind.*, Ser. X, Vol. II, p. 176 (woodcut) (1883).

Anthracotherium magnum; whether they are all entitled to rank as distinct species or whether many of them are to be regarded as races of *Anthracotherium magnum*, is a wide question and one with which I do not propose to deal here. I have, however, carefully compared such figures and descriptions as have been published and actual specimens where they have been available, and have concluded that the *Anthracotherium* of the Bugti Hills is quite distinct both from the varieties as well as from the types of each of the three large European species, which are generally regarded as separate. These three are,—

Anthracotherium magnum Cuvier, type from Cadibona.
Anthracotherium valdense Kowalesky, type from Rosette.
Anthracotherium illyricum Teller, type from Trefail, Styria.

In their general structure these upper molars agree so precisely with the common type of Anthracotherium tooth that it seems needless to enter into much detail in regard to it. There are the four main cusps with an intermediate cusp between the two anterior ones. Osborn's nomenclature is adopted in the sequel in describing the various cusps, columns or tubercles (see also pages 51—52). The two-external cusps (paracone and metacone) each send out a branch partly in the direction of one another and partly outwardly directed. These branches unite and form an upstanding projection from the external wall of the tooth (mesostyle). Another well-marked projection is seen at the antero-external angle of the wall (parastyle), and another at the postero-external angle (metastyle). Posteriorly the enamel forms a broad cingulum culminating in a median tubercle at the entrance of the antero-posterior valley, and continuing though in a less marked degree round to the inner side, where it joins a tubercle situated at the entrance of the transverse valley. Anteriorly there is also a cingulum, which starts from a well-marked tubercle between the protocone and protoconule and continues right to the inside of the tooth until it, too, joins the tubercle at the entrance of the transverse valley.

There seems only need to compare the present molars with those of the three large European species. From *Anthracotherium hyopotamoides* Lydekker, from the same beds in the Bugti Hills, this species is easily distinguished, not only by its size, but also by the form of the loop connecting the outer columns as also by the presence

of parastyle and metastyle and of a cingulum and tubercles connected with it on all sides of the tooth.

As far as size goes it does not seem very feasible to draw any distinction between either of the four large species. Both *A. illyricum* and *A. valdense* have somewhat larger molars than the type specimen of *A. magnum* from Cadibona, but other forms from the Quercy Phosphorites, from Digoin, from Ufshofen, and from Cadibona itself, which have been assigned to *A. magnum*, attain to as great a size, while Filhol[1] believes that he can trace a transition in the other direction from *A. magnum* into the much smaller *A. alsaticum* Cuvier. Therefore, looking only at its size, the present tooth might easily belong to either of the three species. Teller[2] in his admirable descriptions of *A. illyricum* bases one of the specific distinctions between *A. illyricum* and *A. magnum* and *valdense* on the very irregular trapezoid shape of the Styrian species as compared with the almost rectangular outline of the others. In this respect the present species differs from *A. illyricum* and agrees with *A. magnum* and *valdense*, having squarer corners than is even the case in those species. Other important differences are noticeable on the external wall of m^3, in the size and situation of the outer styles. The foremost of these (parastyle) shows a resemblance to *A. illyricum* as distinguished from *A. magnum* by the fact that it is less closely connected with the outer cusp (paracone). Separating the paracone from the parastyle is a broad valley, which does not bend round posteriorly much, as it does in *A. magnum*, but ends abruptly on reaching the outer wall or is continued only as an indistinct cingulum to the entrance of the transverse valley. *A. valdense* is like *A. magnum* except that the parastyle is only slightly developed. These differences are shown in Pl. XII, fig. 1, of Teller's monograph quoted above.

Regarding the mesostyle, this differs in the Bugti species very markedly from each of the three other species both in its position and in its degree of development. It begins more anteriorly and rises exactly opposite the transverse valley instead of rather behind it, as in *A. magnum*. Further, it is very much smaller; however, it is continued backward into a broad cingulum, which completely encircles

[1] H. Filhol: Phosphorites du Quercy, *Ann. Sci. Geol.*, VIII (1877), p. 175.

[2] F. Teller: Neue Anthracotherien reste aus Sudsteiermark und Dalmatien, *Beit. Pal. Ost. Ung.*, IV, p. 82 (1884).

the base of the metacone and joins the metastyle at the postero-external angle. It is the presence of this broad cingulum and the pronounced metastyle that prevents the tooth base from presenting the irregular outline of *A. illyricum*, in spite of the equally great development in both of the parastyle. Coming now to the metastyle we find that its strongest development occurs in *A. illyricum*. In the present species it is somewhat less developed, but more so than in *A. magnum* and very considerably more so than in *A. valdense*, where it is practically absent. Finally the development of a distinct cingulum on the inner side is very noticeable in the present species as contrasted with the very abrupt termination of the cingulum while rounding both inner corners front and back, in each of the three species compared. We may remark that this inner cingulum is also developed in *A. cuvieri* Pomel from Allier. This species is, however, of smaller relative dimensions than the present one, besides differing in other points.

In m^2 the same differences noticed for m^3 also apply for the most part, but in a very much feebler degree. The valley separating parastyle from paracone terminates abruptly without bending to the rear and the mesostyle is somewhat less pronounced than in the European species; m^2, however, has no cingulum on its inner wall which was so striking a feature in m^3.

The following are the measurements in millimetres of these two molar teeth—

	m^2	m^3
Length of outer wall between the antero-external and postero-external angles	47·3	58·9
Length of inner wall at base of crown . . .	45·5	53·3
Breadth of tooth in front half from crown base of protocone to parastyle	51·8	62·8
Breadth of tooth in hinder half from crown base of hypocone to mesostyle	51·9	60·0
Oblique distance between crown base of hypocone and postero-external angle	47·1	50·3

The canine tooth is represented by the almost unworn distal end broken off 83 mm. from the tip and has a longer diameter of 47 mm. and a shorter one of 42 mm., these being both maxima. The surface possesses two narrow longitudinal ridges opposite one another. The line joining the bases of the ridges is inclined at an angle of about 45° to the directions of the maximum and minimum diameters.

SUINA SELENODONTIA.

TETRACUSPIDATI.

MERYCOPOTAMIDÆ.

Genus—TELMATODON nov. gen.

Species—TELMATODON BUGTIENSIS nov. sp.

The generally reprehensible practice of founding a new genus with only such a limited portion of it in one's hand as a single tooth is here adopted in preference to the equally unsatisfactory alternative of leaving a fine specimen nameless and so increasing the difficulty of indexing and future reference.

This genus is founded on the evidence of a last upper molar tooth which, however, possesses characters so unique as to render it impossible to assign it to any one of the previously known genera. It gives us yet another link between the Ruminantia and the Suina and appears to occupy a position intermediate between the Merycopotamidæ and the Anthracotheriidæ.

The tooth under consideration is entirely preserved with the exception of the outer posterior accessory tubercle (metastyle), which has been slightly abraded, and is in a moderately early stage of wear. The absence of a socket on the posterior side indicates it to have been the last molar.

It is rather broader than long and the length is greater externally than it is internally. This can be seen by reference to the measurements on page 54. It is brachyodont and of the general tetracuspidate selenodont type with four primary columns designated according to Osborn's nomenclature as the protocone, paracone, metacone, and hypocone. The parastyle at the antero-external angle is developed

to an extraordinary degree, as is the case in all the species of *Brachyodus* and *Ancodus*. The metastyle at the postero-external angle is developed in quite an analogous way though to a much less marked extent. The paracone and metacone are connected by a pronounced loop projecting on the external wall and constituting the mesostyle,—another feature of the genus *Brachyodus*. In fact it may be regarded almost as a tooth of *Hyopotamus giganteus* Lydekker (which is undoubtedly a *Brachyodus*) without the anterior intermediate cusp (protoconule). The absence of this fifth cusp, however, makes it impossible, according to our present classification, to place our specimen in the Anthracotheriidæ and compels us in spite of its obviously more bunodont character to make room for it among the Merycopotamidæ. It is noteworthy that there is a trace, faint but very distinct, of the protoconule, so that this genus affords us a perfect passage between the two groups. The peculiar characters of the tooth will be sufficiently gathered from the detailed comparisons with known genera which follow.

Apart from the want of the intermediate cusp or protoconule other differences exist between the present genus and *Brachyodus*. The former is more hypsodont. While *Brachyodus*, of which *Brachyodus onoideus* Gerv. may be considered as the type, possesses a well-marked cingulum on three sides, *Telmatodon bugtiensis* only shows a real cingulum anteriorly; on the internal side the walls of both columns slope outward at so great an angle from the vertical (40°), that, what might otherwise be regarded as a cingulum, is inconspicuous. Further in *Brachyodus onoideus* the external walls of the two external columns (paracone and metacone) are regularly concave, whereas in the present genus they possess a strong, broad ridge. To a slight extent an approximation to both these conditions is to be noticed in *Brachyodus giganteus* Lydekker. Considering the roots of this tooth, of the anterior ones, which alone are visible, the exterior one is single and curved in a remarkable manner, while the internal one has a lateral branch. The external columns and styles are very obliquely situated and a line joining protostyle to metastyle touches both the ridges of the two external columns, forming thus a straight line inclined at an angle of 18° to the line of jaw.

As may have been inferred from the previous remarks, the more bunodont character of this tooth prohibits its being referred either to the Oreodontidæ or to the Dichodontidæ. There remain only its

affinities with the various members of the Merycopotamidæ to be considered. At one time or another three genera have been placed in this family, *Merycopotamus*, *Hemimeryx*, and *Chæromeryx*, although Lydekker has considered that the affinities of the last named are rather with the Dichodontidæ. This tooth resembles Merycopotamus in certain ways, as for example in the ridges on the external side of the outer columns. It is, however, easily distinguished from *Merycopotamus :*

1. By the fact that the angles on either side of the outer columns are not folded over towards one another as in that genus, but are very much more open and separated. The external part of the tooth is, so to speak, less squeezed together than in *Merycopotamus.*

2. The loop connecting the external columns is much more strongly developed than in *Merycopotamus.*

3. In the very much greater development of the parastyle.

4. Whereas in *Merycopotamus* the transverse valley is practically open, in this tooth it is to a certain extent closed externally.

5. In the strong outward slope of the internal surfaces of the protocone and hypocone, as before mentioned, and the consequent absence or apparent absence of a cingulum internally. There is likewise no trace of the external cingulum of *Merycopotamus.*

6. Every vestige of an intermediate cusp has disappeared in *Merycopotamus*, which is not the case in the Bugti genus.

There are many other minor differences, but the ones mentioned will serve to sharply separate the two genera.

The present tooth resembles *Hemimeryx* in the oblique direction of the external surfaces of the outer columns and styles, and in the prominence of the mesostyle. The most important differences are :

1. The absence in *Hemimeryx* of any median ridge on the external surfaces of the outer columns.

2. The incomplete protocone in *Hemimeryx.*

3. The absence of a parastyle in *Hemimeryx.*

4. The much stronger development of a cingulum than is the case in the present genus.

This tooth approximates to that of *Chæromeryx* both in the vestigial trace of a protoconule, which is, however, far more pronounced in that genus, and in the compression of the loop connecting the outer columns so that the surfaces of these columns are more ample. Moreover, both genera possess the median ridge on these columns

though it is much wider and more convex in *Telmatodon*. Differences from *Chæromeryx* exist:

1. In the entirely different form of the outer columns. Their general line is more oblique than in that genus, but the most striking point is that in *Chæromeryx* the outer crescents are very much less squeezed together, while the ridges on either side, especially the posterior one, are only slightly pronounced. In consequence of this, their outward concavity is very trifling, which feature gives to *Chæromeryx* that similarity to the Ruminantia which is wanting in *Telmatodon*.

2. In the greater development of the parastyle.

3. In the outward slope of the internal surfaces of the inner columns and the reduction of the cingulum in the same way that has been noticed in comparing my specimen with the other members of the family.

Sufficient has been said to indicate certain marked affinities to each of these three genera, so that, in view of its tetracuspidate character, my specimen can easily be placed in the family of the Merycopotamidæ, although, as explained above, its affinities decidedly lean also in the direction of the Anthracotheriidæ, giving us evidence, like *Chæromeryx*, in the gradual atrophy of the protoconule, of an evolutionary transition from the one of these two families to the other.

The following are the measurements in millimetres of the tooth described above:—

Length of outer wall between the antero-external and postero-external angles	39·1
Length of inner wall at base of crown	34·0
Breadth of tooth in front half from crown base of protocone to parastyle	46·1
Breadth of tooth in hinder half from crown base of hypocone to mesostyle	41·5
Oblique distance between crown base of hypocone and postero-external angle	37·0

Mandible.

It is with great hesitation that I provisionally refer the fragment figured in Pl. 12, figs. 4 and 5, to the same genus as the upper molar described above. Few of the portions, which afford good generic characters, are present in the specimen. It seems, however, to present

differences from the mandible of any other genus, and as its size and general structure are such as might reasonably lead us to suppose that it belonged to the same species as the molar tooth of *Telmatodon*, I have thought it better to assign it to some definite position until further evidence should come to hand.

It is broken off immediately in front of the last lower molar, and although portions of the mandible posterior to the tooth are present, the basal part just behind the notch is absent, so that it is impossible to say whether it possessed a descending flange or not.

Lydekker described[1] and figured three mandibles obtained from a locality in the Bugti Hills very near to and possibly even the same as that from which the present specimens come. He assigned these provisionally to *Anthracotherium hyopotamoides* Lydekker and *Hyopotamus giganteus* Lydekker. These mandibles belonged to a larger animal than this, are distinctly more brachyodont and give indications of having possessed a second tubercle to the talon of the last molar; though this cannot be positively asserted. If either of them are correctly referred to *Anthracotherium*, this second tubercle should certainly be present as it is characteristic of the genus. The genus *Brachyodus* also, as Andrews[2] has observed, has very distinct traces of this second tubercle, in which respect *Anthracotherium* and *Brachyodus* differ from *Ancodus*. In the talon of the present tooth no second tubercle can be traced. My other reasons for not considering this mandible as that of a *Brachyodus* are that it is more hypsodont, that the external wall of the tooth more nearly approaches the vertical, that the outward bending of the loop of the talon is greater, and finally on account of the character of the sculpturing of the surface of the enamel, which is rugose instead of being in fine longitudinal wavy ridges. In this it seems to agree with the upper molar just described. On the other hand it differs from *Ancodus* in the rugose sculpturing of the enamel (in *Ancodus* the enamel is unsculptured), in the greater prominence of the cingulum, and in the more rounded nature of the external crescents. The cingulum is not, however, prominent in the tooth under consideration. It is wanting entirely on the internal edge, but is well marked on the antero-external angle and on the outer side of the talon.

[1] *Pal. Ind.*, Ser. X, Vol. II, pp. 154 and 163, Pl. XXV (1884).

[2] C. W. Andrews: *Geol. Mag.* (4), VI, p. 484 (1899).

Considering now its affinities to the Merycopotamine group, it seems to approach *Merycopotamus* in its hypsodonty, in the outward bending of the crescent of the talon (although this is less marked than is the case in Merycopotamus), and in the character of the jaw, so far as it can be observed. This is extremely wide and massive around the teeth, but suddenly thins basally and still more suddenly posteriorly. Whether it possessed the prominent descending flange of *Merycopotamus* or not, the posterior notch must have been very deep, as it is unlikely that a bone so thin as is the case within the posterior part of this mandible would have been fractured within such a short distance of the base, the inference then being that the base must have extended some considerable distance below the fracture. On the whole its Merycopotamine affinities seem to justify my provisionally placing it in the position that I have. The characters will be sufficiently gathered from the figures (Pl. 12, figs. 4 and 5) and the above description.

EXPLANATION OF PLATE.

PLATE, 12, FIG. 1.—*Anthracotherium bugtiense* nov. sp., last two left upper molars ¾ nat. size.

" FIG. 2.—*Anthracotherium bugtiense* nov. sp., canine ¾ nat. size.

" FIG. 3.—*Telmatodon bugtiensis* nov. sp., last left upper molar. ¾ nat. size.

" FIG. 4.—*Telmatodon bugtiensis?* Left ramus of mandible with last molar (side view) ¾ nat. size.

" FIG. 5.—The same (surface view) ¾ nat. size.

PERMO-CARBONIFEROUS PLANTS FROM KASHMIR. BY A. C. SEWARD, F.R.S., *Professor of Botany, Cambridge.* (With Plate 13.)

IN 1905 a short account was published of plants collected by Dr. Noetling at Khunmu in the Vihi valley, S. E. of Srinagar. All the specimens, with the exception of a single impression referred with some hesitation to the genus Psygmophyllum, were identified as fragments of a new species of Gangamopteris, *G. kashmirensis*.[1] The conclusion arrived at, so far as it was possible to base an opinion on the meagre data available, was that the Khunmu fossils indicated a geological horizon at least as low as the Talchir series. Two new species of fishes, *Amblypterus kashmirensis* and *A. symmetricus*, and one new species of Labrinthodont, *Archegosaurus ornatus*, were described by Dr. Smith Woodward and compared by him with Permian species from European localities.[2] During the summer of 1906 Mr. Hayden collected additional material from the Gangamopteris beds in the neighbourhood of Khunmu and from other localities. This collection was submitted to me for examination by the Director of the Indian Geological Survey, from whom I have also received a proof of Mr. Hayden's paper on "The stratigraphical position of the Gangamopteris beds of Kashmir." The object of Mr. Hayden's visit to Khunmu was to determine the relation of the plant-beds to certain fossiliferous marine strata in the same area. Plants were obtained from the following beds:—A.—An upper band of carbonaceous shale on the main Gangamopteris horizon exposed on the Risin Spur at the mouth of the Nagowan ravine, ⅙ mile N. W. of Khunmu, Viti (Dr. Noetling's locality from which were obtained the plants already described). B.—A lower band of carbonaceous shale at the same place. C.—Bed No. 3, Zewan Spur, near the villages of Panduchak and Zewan, Vidi. From this bed Mr. Oldham and Mr. Hayden collected specimens of Gangamopteris identical with those from locality A. D.—Bed no. 13, a hard siliceous shale exposed in the section which includes bed No. 3 (C). E.—Carbonaceous shale on the left side of Guryul ravine.

[1] Seward and Woodward (05).
[2] *ibid.*

Mr. Hayden has shown that the age of the Gangamopteris beds depends on that assigned to the Zewan rocks; he writes:—"All that we can say at present is that the Gangamopteris beds are not younger than Upper Carboniferous and may belong to the base of that subdivision or even to the Middle Carboniferous." (See *ante*, p. 36.) It only remains to write a report on the palæobotanical records furnished by these Kashmir strata.

With a very few exceptions all the plant fragments belong to leaves of *Gangamopteris kashmirensis*, a species which must have grown in profusion and almost to the exclusion of other plants. The following represents the result of the examination of the material from the five Kashmir localities:—

A.—*Gangamopteris kashmirensis*; one specimen of Cordaites leaf. Most of the material comes from this locality.

B.—A single specimen of *G. kashmirensis*.

C.—This, the second richest locality, has afforded *G. kashmirensis* in abundance, together with fragments of *Psygmophyllum Hollandi* and Cordaites.

D.—A few fragments including Gangamopteris and Cordaites.

E.—This bed has so far yielded no satisfactory specimens, but some of the fragments appear to be identical with *G. kashmirensis*.

Description of Specimens.

Gangamopteris kashmirensis Sew.—The majority of the specimens from the richest localities A and C add nothing to our knowledge of this species, but a few examples occur which enable us to amplify the definition of the species as regards the form of the apex of the frond, which was not preserved in any of the specimens previously obtained.

In the definition of the species based on the earlier collection the apical portion of the leaf is described as broadly lanceolate; this is borne out by such a specimen as that represented in fig. 2, Pl. 13, but the example shown in fig. 1, which is broken just short of the tip, possesses a much more gradually tapered apex which can hardly be described as broadly lanceolate. The apex represented in fig. 1 is distinct from that of any species of Gangamopteris or Glossopteris hitherto figured, and it affords some confirmation of my description of the Khunmu plant as a new species. The secondary

veins are indicated in the lower part of the fragment, but from the upper portion they have been entirely obliterated. The shorter and broader form shown in fig. 2 (loc. A) exhibits the characteristic venation with greater clearness. A second example of the narrower type of apex was obtained from locality D.

PSYGMOPHYLLUM HOLLANDI sp. nov. Pl. 13, figs. 3—6.

My former account of Kashmir plants contains a description and a figure of a specimen described as *? Psygmophyllum* sp. The impression was described as part of the lamina of a leaf apparently divided into two symmetrical halves. Specimens from localities C and D supply further information in regard to this type of leaf, and, if I am right in regarding the new specimens as specifically identical with the solitary example hitherto described, they lend support to the generic designation adopted.

Fig. 3, Pl. 13, from locality C represents what is probably half a lamina similar to the specimen shown in fig. 3 of my former paper. The venation is not distinctly preserved, but it appears to be that of Psygmophyllum. This fragment regarded by itself might equally well be placed in the genus Ginkgo, but the evidence afforded by others is more in accordance with the adoption of the name Psygmophyllum. It is, however, difficult to speak with confidence as regards the choice between the genera Baiera, Ginkgo, and Psygmophyllum: it is indeed not improbable that the three plants are all members of the same group, the Ginkgoales. The specimen shown in fig. 4 consists of part of a leaf with a short basal portion and a bilobed lamina which represents half a wedge-shaped leaf divided into two symmetrical halves by a deep median sinus. The dotted line in the drawing indicates the supposed outline of the complete leaf; a few veins are obscurely indicated in one part of the lamina.

Fig. 5, Pl. 13 (loc. C), shows part of two leaves like that represented in fig. 4; that to the left of the axis is the best specimen so far obtained. From the axis which lies between the leaves short branches are given off at *a* which agree in breadth with the basal part of the leaf represented in fig. 4 and may be the remains of leaf-bases. Although there is no absolute proof of a connection between the axis and leaves, I am inclined to regard both as parts of the same plant. The fragment shown in fig. 6 is from locality D; this may be a piece of a leaf like that of figs. 4 and 5. Traces of veins are faintly preserved.

The specimen represented in fig. 5 bears a striking resemblance to *Psygmophyllum Kidstoni*[1] from the Lower Karroo beds of Vereeniging, South Africa, and this similarity constitutes an argument in favour of the use of the designation Psygmophyllum. This genus ranges from the Permian to the Lower Carboniferous and is thus not inconsistent with the views expressed by Hayden as to the geological age of the Kashmir rocks.

It is noteworthy that the pinnules of a plant described by Schmaulhausen from Upper Devonian strata of Russia as *Archæopteris archetypus*[2] are very similar, except in their smaller size, to the leaves of the Indian species.

CORDAITES sp.

The small paralleled veined leaf from locality A represented in fig. 7 (4·7 cm. long and 1·1 cm. broad) has an obtuse but imperfect apex and a truncated base: the veins are rather obscure; at the apex they are seen to diverge very slightly towards the edge of the lamina. In the example from locality C, fig. 8, the apex is clearly preserved and the veins are fairly distinct. These specimens present a close resemblance to the smaller leaves referred by Feistmantel to *Noeggerathiopsis Hislopi* from the Lower Gondwana series of India[3] and may be specifically identical with that species: for reasons which it is not necessary to recapitulate here I prefer to adopt the generic name Cordaites in preference to that of Noeggerathiopsis on the ground that Neoggerathiopsis is probably not distinct from the widely distributed northern type. The smaller of the leaves figured by Schmaulhausen[4] as *Rhiptozamites Goepperti* from Russian rocks originally assigned to a Jurassic age, but more recently, and no doubt correctly, transferred by Zeiller[5] to a Permian horizon, presents a close resemblance to the Kashmir fossils.

Conclusion.

As regards the bearing of this additional material on the question of geological age, Psygmophyllum is consistent with any horizon

[1] Seward (03), Pl. XII, p. 93.
[2] Schmaulhausen (94), Pl. II.
[3] Feistmantel (79), Pl. XIX.
[4] Schmaulhausen (79), Pl. VII, figs. 23—27.
[5] Zeiller (96).

from the Permian down to the Lower Carboniferous. Cordaites has a similar range; Gangamopteris is characteristic of the Lower Gondwana series in India and of rocks occupying a corresponding position in other parts of Gondwana Land, but it is not surprising to find a new type of the genus in beds which are at least not younger than the upper division of the Carboniferous system.

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EXPLANATION OF PLATE.

(All the figures are reproduced nature size.)

PLATE 13, FIGS. 1 & 2.—*Gangamopteris kashmirensis*, from Risin spur (loc. A).
" " 3—6.—*Psygmophyllum Hollandi* sp. nov.
Figs. 3—5 from Zewan spur (loc. C).
Fig. 6.—Zewan spur (loc. D).
" " 7 & 8.—*Cordaites sp.*
Fig. 8.—Risin spur (loc. A).

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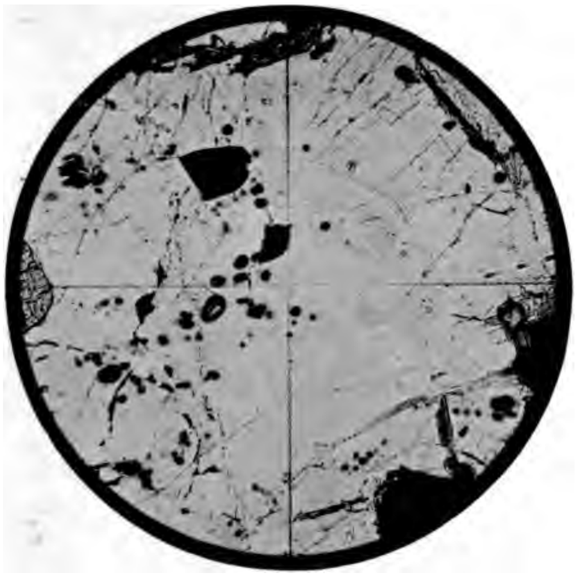

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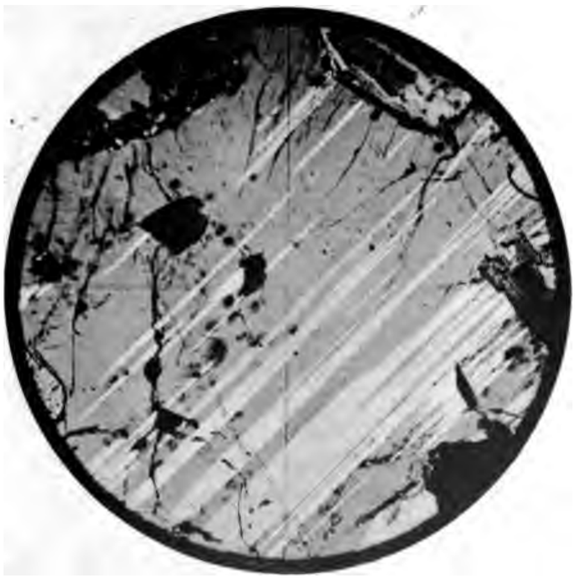

FIG. 2.

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SAPPHIRINE- AND SPINEL-BEARING ROCKS OF VIZAGAPATAM.

Fig. 1.

Fig. 2.

Microphoto. by T. L. Walker.

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SAPPHIRINE- AND SPINEL-BEARING ROCKS OF VIZAGAPATAM.

FIG. 1.

FIG. 2.

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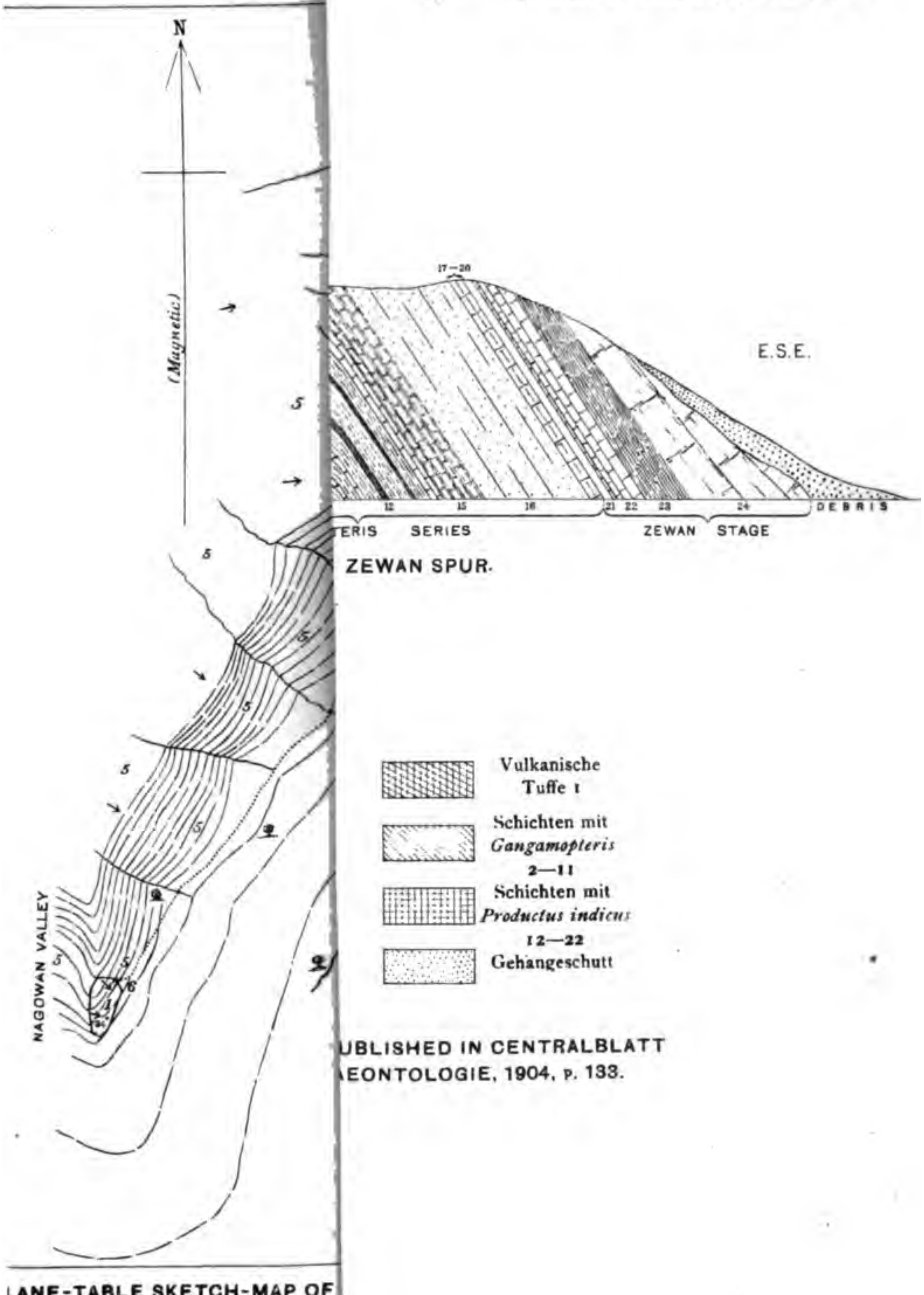
SAPPHIRINE- AND SPINEL-BEARING ROCKS OF VIZAGAPATAM.



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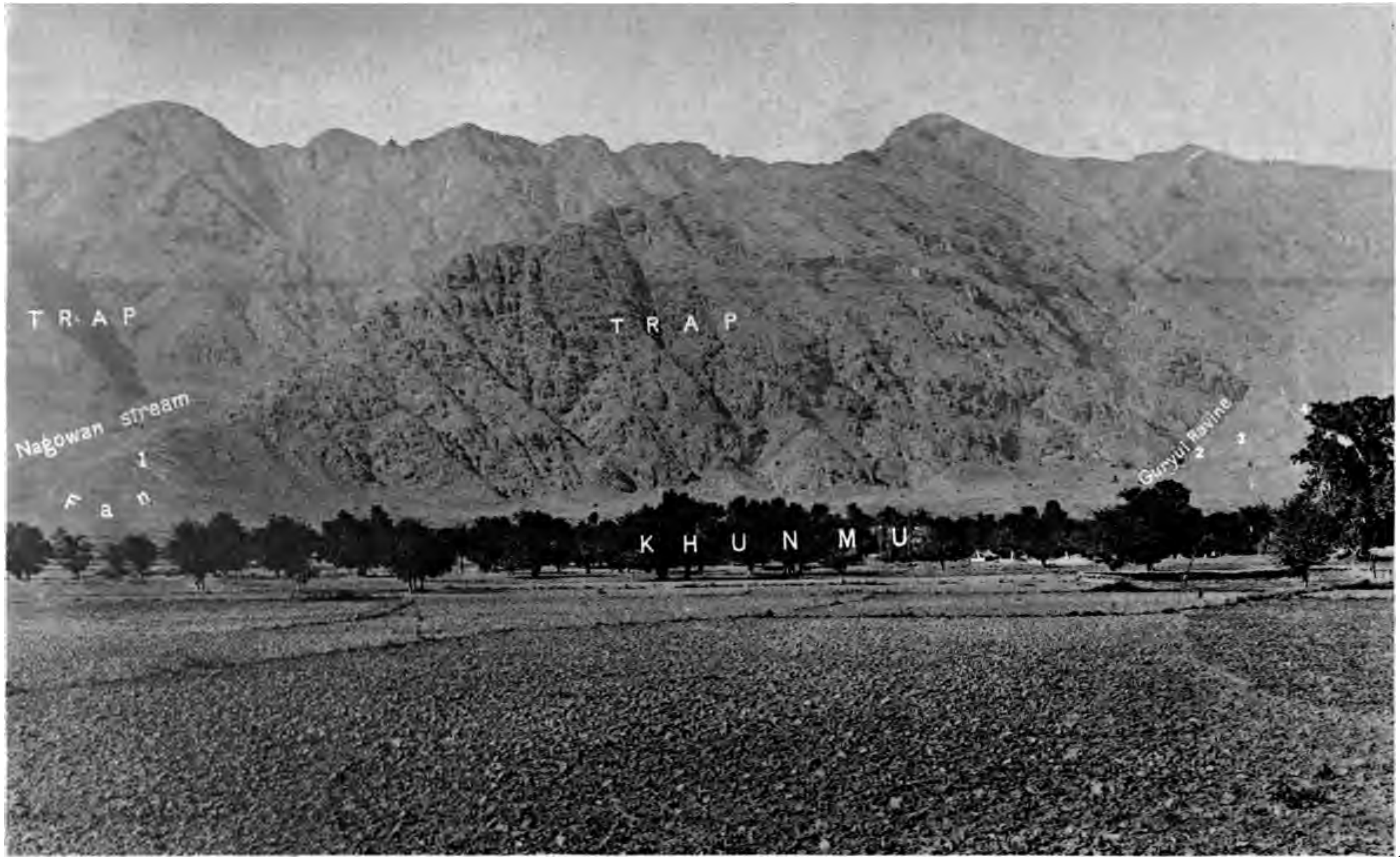

Photo. by H. H. Hayden. Bemrose, Collo., Derby.

HILLS NORTH-WEST OF KHUNMU.

Photo. by H. H. Hayden.

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FRONT VIEW OF GANGAMOPTERIS BEDS, KHUNMU.

(*Dr. Noetling's original locality.*)

Photo. by H. H. Hayden.

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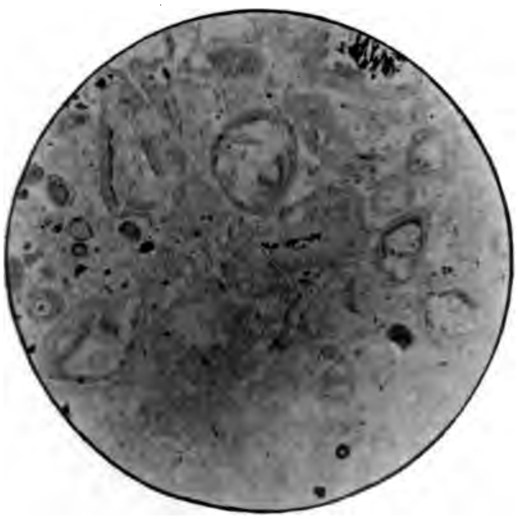
RIDGE NEAR ZEWAN, VIHI (KASHMIR).

Fig. 1.

Fig. 2.



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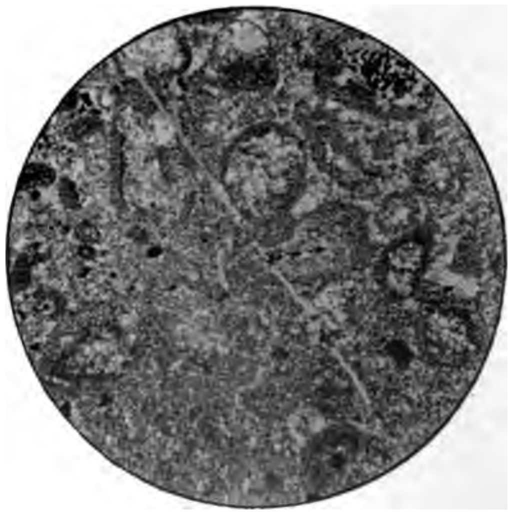

Fig. 4.

Microphoto. by H. H. Hayden.

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LIMESTONES AND CHERTS OF VIHI, KASHMIR.

GEOLOGICAL SURVEY OF INDIA.

Records, Vol. XXXVI, Pl. 9

FIG. 1.

FIG. 2.

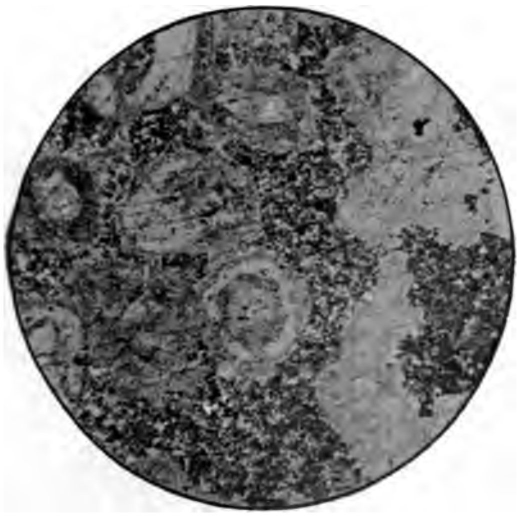

FIG. 3.

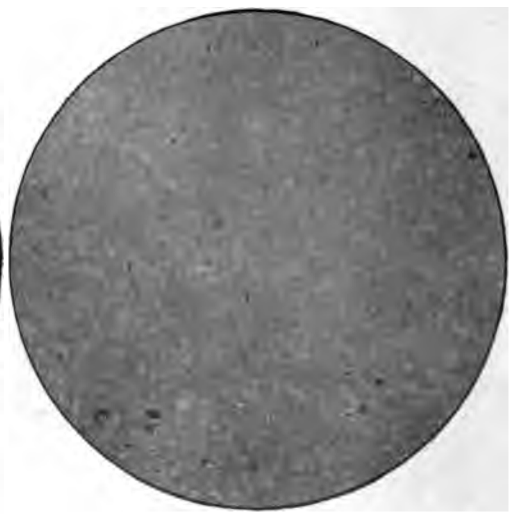

FIG. 4.

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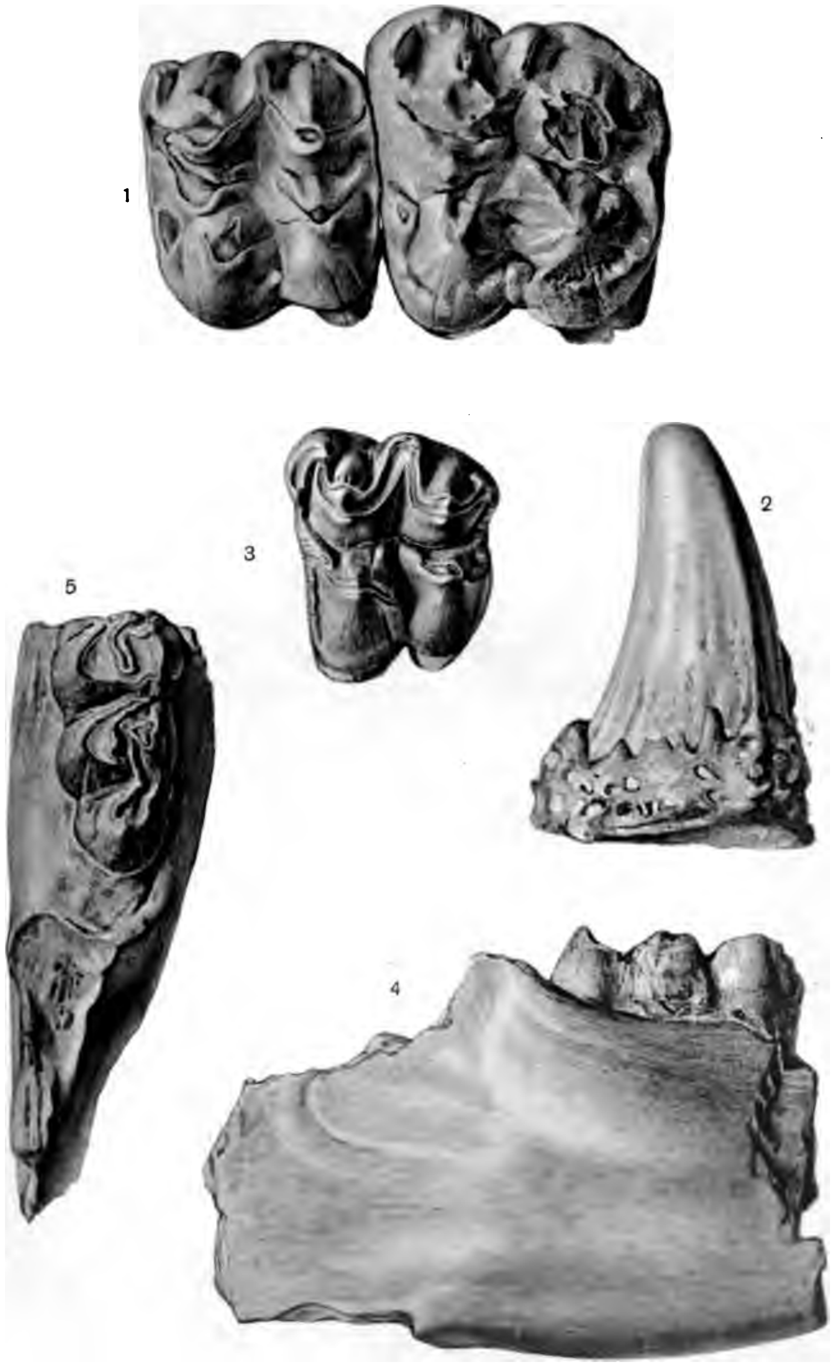
LIMESTONES AND NOVACULITES OF VIHI, KASHMIR.

Photo. by T. D. La Touche.

BASALT DYKE, N. SIDE OF LOI HAN̈ HUN̈.

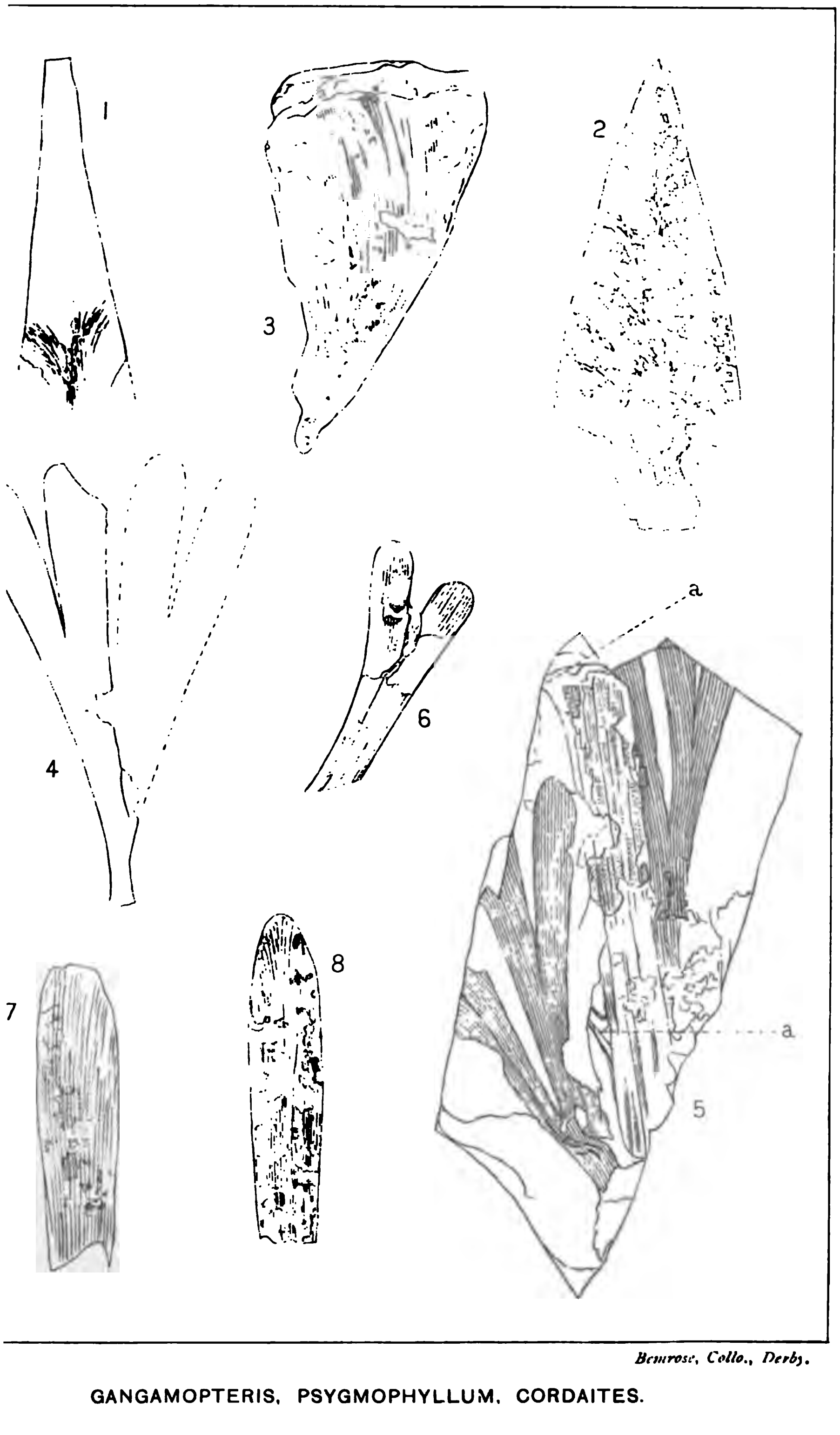
COLUMNAR BASALT, SUMMIT OF LOI HAÑ HUÑ.



M. Woodward, del. *Bemrose, Collo., Derby.*

NEW SUIDAE, FROM THE BUGTI HILLS, BALUCHISTÁN.

ALL FIGURES $\frac{2}{3}$ NATURAL SIZE.



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GANGAMOPTERIS, PSYGMOPHYLLUM, CORDAITES.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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Part. 2.] 1907. [December.

THE MINERAL PRODUCTION OF INDIA DURING 1906. BY T. H. HOLLAND, F.R.S., *Director, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTION.

THIS summary of the returns for Mineral Production in India during 1906 is given in the form adopted for 1904 (*Records*, Vol. XXXIII, Part 1) and for 1905 (*Records*, Vol. XXXIV, Part 2). Fuller details concerning the principal mineral occurrences of the country known up to the end of 1903 are given in the Review of Mineral Production for the years 1898 to 1903 (*Records*, Vol. XXXII, Part 1). Later additions to our knowledge of mineral occurrences in India will be summarised in the Quinquennial Review to be published as soon as possible after the close of the period 1904—1908.

A full statement of production and statistics regarding labour at the mines regulated by the Indian Mines Act of 1901 has been published with the Annual Report of the Chief Inspector of Mines. The totals given by the Chief Inspector both for output and labour refer only to mines under the Act, and thus do not include the production of mines in Native States, or the output of numerous minor products raised from the superficial workings to which the Act has not yet been applied. The present statement, however, includes as many of these products as have been reported by Local Governments and States, the minerals being divided as before into two groups, namely,—

Group I for which approximately full returns are obtainable, and

Group II for which the returns are admittedly incomplete or only approximately estimated.

For the future all returns for mineral production will be sent by Local Governments and Political Agents direct to the Geological Survey Office, and it is hoped that this system will permit of a more thorough and prompt check of the figures with a view of increasing Group I at the expense of Group II. It will be noticed that a certain number of corrections have been made in the figures reported for 1905, and where changes have been made in the method of estimating values for 1906, corresponding corrections have been made in the figures for 1905.

Total value of production.

Although there has been considerable variations in the production during the past year the total value of the minerals of Group I for 1906 exceeds that for the same minerals raised in 1905 by £622,870, or an increase of 10·9 per cent. (see table 1).

There was a considerable increase in the number of concessions granted for prospecting and mining, the total number of licenses and leases granted in Government lands having risen from 189 in 1905 to 252 in 1906. The licenses and leases granted in alienated lands and in the various States have not been reported.

Prospecting and mining concessions.

TABLE 1.—*Total Value of Minerals for which Returns of Production are available for the years 1905 and 1906.*

MINERAL.	1905.	1906.
	£	£
Gold	2,416,971	2,230,284
Coal (*a*)	1,419,443	1,912,042
Petroleum (*a*)	604,203	574,238
Salt (*a*)	441,392	420,901
Saltpetre (*b*)	235,723	270,547
Manganese-ore (*b*)	248,309	435,268
Mica (*b*)	142,008	259,544
Ruby, Sapphire, and Spinel	88,340	96,867
Jadestone (*b*)	45,474	64,433
Graphite	16,890	10,009
Iron-ore (*a*)	13,827	11,341
Tin-ore (*a*)	9,917	13,799
Chromite (*a*)	3,482	7,188
Diamonds	2,474	5,160
Magnesite (*a*)	550	488
Amber	945	709
TOTAL	5,689,948	6,312,818

(*a*) Spot prices. (*b*) Export values.

II.—MINERALS OF GROUP I.

Chromite.	Graphite.	Manganese-ore.	Salt.
Coal	Iron-ore.	Mica.	Saltpetre.
Diamonds.	Jadeite.	Petroleum.	Tin.
Gold.	Magnesite.	Ruby, Saphire, and Spinel.	

Chromite.

There was a marked increase in the production of chromite in Baluchistan, namely, from 2,708 tons, valued at £3,482, in 1905, to 4,375 tons, valued at £7,188, in 1906. Table 2 gives the figures since 1903. The values reported for 1906 also show an increase in the average value per ton as well as in the total.

TABLE 2.—*Production of Chromite in Baluchistan since the commencement in 1903.*

YEAR.	Quantity.	*Value.*	Value per ton.
	Tons.	£	Shillings.
1903	248	*327*	23·0
1904	3,596	*4,137*	23·0
1905	2,708	*3,482*	25·7
1906	4,375	*7,188*	32·9

Coal.

Total production, value, and average price of coal.

The output of coal for 1906 shows that the activity previously reported has again been extended, the total production having risen from 8,417,739 statute tons in 1905 to 9,783,250 tons in 1906, an increase of 16·2 per cent. On account of the higher prices maintained throughout the year there has been a still greater proportionate increase in reported spot value. The total value returned for 1905 was £1,419,443; for 1906 the total reported was £1,912,042, that is an increase of 34·7 per cent. The average price per ton reported as the spot value of

Indian coal in 1905 was 3*s*. 4*d*.; in 1906 the average of the figures returned was 3*s*. 11*d*. per ton. The spot prices naturally do not correspond to fuel value, for Bengal coal, which is, all round, the best worked, brought an average price during 1906 of only 3*s*. 6*d*.

TABLE 3.—*Production and Value of Coal during the years 1904—1906.*

YEAR.	Quantity.	Total Value at the Mines.		Average Value per ton at the Mines.	
	Statute Tons.	*Rupees.*	£	*Rs. as.*	*s. d.*
1904	8,216,706	*2,09,82,407*	1,398,826	*2 9*	3 5
1905	8,417,739	*2,12,91,649*	1,419,443	*2 8*	3 4
1906	9,783,250	*2,86,80,655*	1,912,042	*2 15*	3 11

TABLE 4.—*Provincial Production of Coal for the years 1904—1906.*

PROVINCE.	1904.		1905.		1906.	
	Quantity.	*Value.*	Quantity	*Value.*	Quantity.	*Value.*
	Statute Tons.	£	Statute Tons.	£	Statute Tons.	£
Baluchistan . . .	49,867	*27,308*	41,725	*23,658*	42,164	*22,299*
Bengal	7,063,680	*1,015,147*	7,234,103	*1,042,223*	8,617,820	*1,521,057*
Burma	1,105	*294*	...	...	1,222	*305*
Central India . . .	185,774	*47,060*	157,701	*40,137*	170,292	*41,898*
Central Provinces . .	139,027	*43,664*	147,265	*44,452*	92,848	*26,296*
Eastern Bengal and Assam	266,765	*84,592*	277,065	*87,826*	285,490	*90,431*
Hyderabad . . .	419,546	*150,345*	454,294	*140,074*	467,923	*167,606*
Kashmir . . .	270	(*a*)	...	...	...	...
Punjab	45,594	*22,144*	62,622	*34,166*	73,119	*36,301*
Rajputana (Bikanir)	45,078	*8,272*	42,964	*6,907*	32,372	*5,849*
TOTAL .	**8,216,706**	*1,398,826*	**8,417,739**	*1,419,443*	**9,783,250**	*1,912,042*

It will be noticed from tables 5, 6, and 7 that the increase in the total is mainly contributed by the Gondwana fields, especially those of Bengal. The Jherria field has at last taken the lead among the coalfields, while the Raniganj field, which has hitherto been the greatest producer, drops to second place. An interesting development is that of the Pench Valley field in the Central Provinces, showing an output of 32,102 tons in spite of the imperfect railway facilities so far serving the field.

TABLE 5.—*Origin of Indian Coal raised during 1904—1906.*

—	1904.	1905.	1906.
	Statute Tons.	Statute Tons.	Statute Tons.
From Gondwana coalfields . . .	7,808,027	7,993,363	9,348,884
From Tertiary coalfields . . .	408,679	424,376	434,367
TOTAL, Statute Tons .	**8,216,706**	**8,417,739**	**9,783,251**
Total, Metric Tons .	*8,348,561*	*8,552,422*	*9,940,246*

TABLE 6.—*Output of Gondwana Coalfields during 1904—1906.*

COALFIELDS.	1904.		1905.		1906.	
	Statute Tons.	Per cent. of Indian Total.	Statute Tons.	Per cent. of Indian Total.	Statute Tons.	Per cent. of Indian Total.
Bengal—						
Daltonganj . .	50,517	·61	71,294	·85	87,768	·89
Giridih . . .	773,128	9·41	829,271	9·85	803,321	8·21
Jherria . . .	2,889,504	35·17	3,070,588	36·48	4,076,591	41·67
Rajmahal . .	274	...	414	..	577	...
Raniganj . .	3,350,257	40·77	3,262,536	38·77	3,650,563	37·32
Central India—						
Umaria . . .	185,774	2·26	157,701	1·87	170,292	1·74
Central Provinces—						
Bellarpur . .	90	...	148	·02	916	·34
Pench Valley . .	...	...	1,104		32,102	
Mohpani . .	26,618	·32	22,998	·27	27,503	·28
Warora . . .	112,319	1·37	123,015	1·46	32,327	·33
Hyderabad—						
Singareni . .	419,546	5·11	454,294	5·38	467,924	4·78
TOTAL .	**7,808,027**	95·02	**7,993,363**	94·95	**9,348,884**	95·56

TABLE 7.—*Production of Tertiary Coal in 1904—1906.*

COALFIELDS.	1904.		1905.		1906	
	Statute Tons.	Per cent. of Indian Total.	Statute Tons.	Per cent. of Indian Total.	Statute Tons.	Per cent. of Indian Total.
Baluchistan—						
Khost . . .	38,574	·47	34,140	·41	32,500	·33
Sor Range, Mach, etc.	11,293	·14	7,585	·09	9,664	·10
Burma—						
Shwebo . .	1,105		*Nil*	...	...	...
Upper Chindwin	*Nil*	·02	*Nil*	...	1,222	·01
Kashmir—						
Ladda . . .	270		*Nil*	...	...	...
Eastern Bengal and Assam—						
Makum . . .	266,265	3·25	276,577	·29	285,402	2·92
Smaller fields . .	500		488		88	
Punjab—			277065		285490	
Salt Range . .	45,258	·55	61,618		57,438	
Attock district .	336		715	·75	10	·75
Shahpur " . .	...	...	289		15,671	
Rajputana—						
Bikanir . . .	45,078	·55	42,964	·51	32,372	·33
TOTAL .	408,679	4·98	424,376	5·05	434,367	4·44

Exports.

The external demand for Indian coal has increased with the general rise of prices, and the reduction of Japanese supplies has permitted a sensible increase of the exports to Singapore. The total quantity exported during 1906 for the first time exceeds a million tons (see table 8).

TABLE 8.—*Exports of Indian Coal during 1904—1906.*

Exported to	1904.	1905.	1906.
	Tons.	Tons.	Tons.
Aden	31,620	29,312	19,233
Africa, East	21,263	15,034	13,543
Ceylon	360,697	376,853	416,202
Straits Settlements	144,545	229,230	317,655
Sumatra	32,810	33,859	71,482
Other countries	11,875	99,472	169,678
TOTAL .	602,810	783,760	1,007,793

The large quantities sent to "Other countries" during 1905 and 1906 are mainly due to a sudden demand for Indian coal in China, mainly because of the curtailment of supplies from Japan.

Imports.

Imports of coal are still small though they increased slightly from 188,677 tons in 1905 to 215,712 tons in 1906.

Consumption.

The consumption of Indian coal on Indian Railways was 2,878,281 tons in 1906, which was 29·4 per cent. of the total production, as against an average of 29·8 per cent. for the previous five years. The total consumption of coal increased by 1,161,850 tons, but, on account of the great increase in export, the amount of Indian coal consumed in the country increased at a slightly lower rate than the production (table 9).

Labour.

The average daily attendance at Indian coal mines in 1906 was 99,138, and the average output per person employed 98·68 tons, as against 93·5 tons in 1905 and 88·6 tons in 1904. The low results recorded for years before 1905 are due partly to defective returns, but during the last two years the improvement in output per person employed faithfully reflects the advantages of mechanical assistance in handling the coal. Improvement is shown in the total as well as in the output per person employed below ground. In 1905 the output per person employed below ground was 136·6 tons; in 1906 the output rose to 145·0 tons.

TABLE 9.—*Relation of Consumption to Production of Coal during 1904—1906.*

YEAR.	Total Consumption of Coal in India.	CONSUMPTION OF INDIAN COAL IN INDIA.	
		Quantity.	Percentage of Indian Production.
	Tons.	Tons.	
1904	7,884,140	7,613,896	92·7
1905	7,846,554	7,633,979	90·7
1906	9,008,404	8,775,457	89·7

Diamonds.

The diamonds obtained in the Central Indian States of Panna, Charkhari, and Ajaigarh during 1906 were valued at £5,160, which is a marked improvement on the values reported for previous years (table 10).

TABLE 10.—*Production of Diamonds in Central India.*

YEAR.	Quantity.	*Value.*
	Carats.	£
1904	286·48	*2,636*
1905	172·41	*2,474*
1906	305·91	*5,160*

The principal increase is due to the State of Panna, which contributed diamonds to the value of £4,348 in 1906, against only £1,829 in 1905. The daily average attendance of workers is returned as 2,051 for the whole diamond fields during 1906, against 1,890 reported for 1905.

Gold.

The year 1906 marks the first interruption in the increase of gold production in Mysore, the total value of the output having fallen below that for 1905 by £195,821. The returns for other areas shown in table 11 call for no special remark in an annual statement.

TABLE 11.—*Quantity and Value of Gold produced in India during 1904—1906.*

PROVINCE.	1904.		1905.		1906.	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Ounces.	£	Ounces.	£	Ounces.	£
Bombay—						
Dharwar .	...	...	93	321	60	232
Burma—						
Pakôkku .	...	...	1½	7	1·3	5
Myitkyina .	216	810	620	2,412	2,300	8,850
Hyderabad .	10,559	40,624	13,167	50,060	13,782	52,801
Mysore . .	607,57	2,323,183	616,758	2,363,457	565,208	2,167,636
Punjab . .	370	1,379	176	703	190	746
United Provinces	23	83	2½	11	3·6	14
TOTAL .	618,746	2,366,079	630,818	2,416,971	581,545	2,230,284

TABLE 12.—*Output of Gold from the Hutti Mine, Hyderabad.*

YEAR.	Quantity.	*Value.*
	Ounces.	£
1903	3,809·4	14,505
1904	10,558·6	40,624
1905	13,167	50,060
1906	13,784	52,801
TOTAL .	41,319	157,990

Graphite.

The total production of crude graphite in 1906 was returned as 2,600 tons, valued at £10,009, against 2,324 tons, valued at £16,890, in 1905.

Iron-ore.

The production of iron-ore during 1906 was only 74,106 tons, against 102,529 tons in 1905 and 71,608 tons in 1904. The output is dominated by the quantity raised for the Barakar iron-works which is the only institution smelting on European lines. For the Barakar works the quantity raised in 1906 was returned as 69,397 tons. There was a considerable increase in the number of small native-furnaces in the Central Provinces, the total for 1906 being 379, against 279 for 1905. Returns for labour have been received from most districts and States. The average daily attendance in 1905 amounted to 2,060 and in 1906 to 3,269.

TABLE 13.—*Quantity and Value of Iron-ore raised during the years 1904—1906.*

PROVINCE.	1904.		1905.		1906.	
	Quantity.	*Value.*	Quantity.	*Value.*	Quantity.	*Value.*
	Tons.	£	Tons.	£	Tons.	£
Bengal . . .	65,115	*9,698*	97,698	*12,538*	69,397	*10,085*
Other Provinces and States	6,493	*1,731*	4,831	*1,289*	4,709	*1,256*
TOTAL, Statute Tons & £	**71,608**	*11,429*	**102,529**	*13,827*	**74,106**	*11,341*
Total, Metric Tons .	*72,757*	...	*104,174*	...	*75,295*	...

Jadeite.

There was a slight decrease in the production of jadeite in the Myitkyina district of Upper Burma due to scarcity of labour; the returns for 1906 showed a production of 2,214½ cwts. only, against 2,685

cwts. in 1905. The trade through Rangoon, however, showed a marked increase in the value of the mineral exported as shown in table 14.

TABLE 14.—*Export of Jadestone through Rangoon during the years 1902—1906.*

YEAR.	Weight.	*Value.*	Value per cwt.
	Cwts.	£	£
1902	3,843	36,850	9·59
1903	2,192	50,582	23·08
1904	2,869	43,946	15·32
1905	2,342	43,474	18·56
1906	2,566	64,433	25·11
Average	**2,762**	**47,857**	**17·33**

The average daily attendance of workers at the jadestone quarries in Myitkyina during 1905 was 1,085, and during 1906, 1,038.

Magnesite.

The amount of magnesite raised in the Chalk Hills near Salem in 1906 was 1,832 tons, against 2,063 tons in 1905. The local value of the mineral is returned as only Rs. 4 per ton, and this figure has been taken for estimating the value of the magnesite raised during previous years at the same place. There was an average daily attendance at the Salem magnesite quarries during 1905 of 105 workers; for 1906 the average reported is 87.

Manganese-ore.

The most conspicuous increase in production during the past year was in manganese-ore. The total returned for 1906 was 495,730 tons, against 253,896 tons in 1905 and only 150,297 tons in 1904. The total returned for 1906 is probably slightly below the actual, as no

production has been reported from two of the States in which prospecting operations have been carried on actively, but it will be possible to introduce these corrections next year.

The heavy production was, of course, due to the maintenance of high prices in Europe and America; low-grade ores that were sold at a profit last year would not have paid the freight charges in 1904 and the early part of 1905. During 1904 the unit value of manganese-ores carrying over 50 per cent. Mn at United Kingdom ports was only about 9*d.* to 9½*d.*; but about April 1905 there was a tendency for prices to rise, and by August 1905 the unit value was 10*d.* to 11*d.*, rising to 1*s.* for the last quarter of 1905. In 1906 there was a further increase to 1*s.* 1*d.* for the first quarter, and about 1*s.* 2*d.* during May and June, whilst before the close of the year the first-grade ore brought 1*s.* 4½*d.* per unit. Thus the prices were nearly doubled in two years, with the result that larger quantities of the lower grades have been raised and exported, while new quarries have been opened, and great activity in prospecting has followed. India is now probably the largest producer of high-grade manganese-ore, exporting about as much as was obtained from Russia before her mines were so disorganised by internal political disturbances.

Table 15 shows the provincial production for 1906 compared with that for 1904 and 1905.

TABLE 15.—*Production of Manganese-ore for 1904—1906.*

PROVINCE.	1904.	1905.	1906.
	Statute Tons.	Statute Tons.	Statute Tons.
Bombay	*Nil*	......	7,517
Central India	11,564	30,251	50,074
Central Provinces	85,034	159,950	320,759
Madras	53,699	63,695	117,380
TOTAL, Statute Tons .	**150,297**	253,896	**495,730**
Total, Metric Tons .	152,708	257,969	503,684

The labour returns for 1905 show an average daily attendance at manganese-ore quarries of 6,811, while for 1906 the total rose to 12,607, exclusive of the workers employed in Sandur and Mysore.

Mica.

The great increase in the weight of exported mica which was referred to last year (*Rec. Geol. Surv. Ind.*, XXXIV, 57) was due to an error in the returns; the correct figure for 1905 was 25,837 cwts.; but during 1906 the exports were more than doubled in weight and largely though not proportionately increased in value. The total weight of mica exported in 1906 was 54,193 cwts., valued at £258,782, against 25,837 cwts., valued at £142,008, in 1905. Table 16 shows the figures for the past five years.

TABLE 16.—*Exports of Mica during the five years 1902—1906.*

YEAR.	Weight.	*Value.*	Value per cwt.
	Cwt.	£	£
1902	17,786	*76,056*	4·28
1903	22,106	*90,297*	4·09
1904	18,250	*83,183*	4·56
1905	25,837	*142,008*	5·50
1906	54,193	*258,782*	4·78

It is satisfactory to notice that the returns for production are now in fair agreement with the more accurate figures obtainable for exports. There are still a few areas from which only imperfect figures are obtainable, and the practice of stealing from waste-heaps and mines, which formerly helped to accentuate the great difference between reported production and export, has been considerably reduced. Table 17 shows the provincial returns for 1904, 1905, and 1906.

TABLE 17.—*Provincial Production of Mica for 1904—1906.*

PROVINCE.	1904.	1905.	1906.
	Cwts.	Cwts.	Cwts.
Bengal	14,601	14,601	22,360
Madras	8,280	8,280	24,420
Rajputana	2,760	2,760	5,763
TOTAL .	25,641	25,641	52,543

The returns for labour show for 1905 a total average daily attendance at mica mines of 15,244 workers; for 1906 the total was 15,723.

Petroleum.

There was a slight drop in the production for 1906 as compared with 1905; but, as shown in table 18, a considerable increase as compared with the petroleum produced in 1904.

TABLE 18.—*Production of Petroleum during 1904—1906.*

PROVINCE.	1904.	1905.	1906.
	Gallons.	Gallons.	Gallons.
Burma	115,903,804	142,063,846	137,654,261
Eastern Bengal and Assam . .	2,585,920	2,733,110	2,897,990
Punjab	1,658	1,488	871
TOTAL .	118,491,382	144,798,444	140,553,122

The decrease in production was due mainly to the Yenangyat and Singu fields in Burma (see table 19) although in the latter area the output was artificially restricted. The local value is estimated at about one anna (1*d.*) per gallon of crude oil.

TABLE 19.—*Production of the Burma Oilfields for 1904—1906.*

OILFIELD AND DISTRICT.	1904.	1905.	1906.
	Gallons.	*Gallons.*	Gallons.
Akyab	47,082	53,455	35,423
Kyaukphyu	89,827	60,647	53,429
Yenangyaung, Magwé	73,428,960	85,648,749	89,549,252
Singu, Myingyán	23,677,450	37,541,177	34,843,621
Yenangyát, Pakôkku	18,660,485	18,759,818	13,172,136
Thayetmyo	...	...	400
TOTAL .	115 903,804	142,063,846	137,654,261

The average daily attendances of workers on the Burma oilfields amounted to 1,292 during 1905, and to 1,837 during 1906.

The agreement made between the Burma Oil Company and the producers in the Dutch East Indies has tended to reduce the figures both for imports of foreign kerosene and for exports of Burma oil, although the figures for the former are largely affected by the failure of Russian supplies. Tables 20 and 21 show the variations for the past five years.

TABLE 20.—*Imports of Kerosene during the five years 1902—1906.*

Imported from	1902.	1903.	1904.	1905.	1906.
	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
Russia	71,995,767	65,434,324	42,256,738	17,205,175	...
United States . .	8,052,364	7,588,569	7,628,275	18,737,577	28,494,794
Borneo	...	1,078,719	6,931,291	7,039,812	1,795,715
Straits Settlements .	1,332,779	1,280,507	8,985,538	12,508,844	8,499,198
Sumatra . . .	285,990	974,981	3,566,619	6,816,991	9,731,405
Other countries . .	291,487	4,479	1,222,397	16,363	6,663
TOTAL .	81,958,387	76,361,579	70,590,858	62,324,762	48,527,77[illegible]

TABLE 21.—*Exports of Mineral Oil and Paraffin Wax during the five years 1902—1906.**

YEAR.	Mineral oil.	Paraffin wax.
	Gallons	Cwts.
1902	44,002	65,041
1903	747,834	43,206
1904	3,787,677	42,940
1905	2,422,589	63,966
1906	903,545	61,097

Ruby, Sapphire, and Spinel.

The output of ruby, sapphire, and spinel reported by the Burma Ruby Mines Company during the year ending February 28th, 1907, was reported as 326,855 carats, valued at £95,540, against a value of £88,340 returned for the corresponding period 1905-06. Of the total value £93,023 is due to the rubies obtained; the sapphires were valued at £1,132 and spinels at £1,385. The average daily attendances of workers during 1905 amounted to 1,805, and during 1906 to 2,367, in the Ruby Mines District of Burma.

During the year the Kashmir sapphire-mines were again worked and a production of 2,837 carats, valued at £1,327, was reported.

Salt.

There was an unimportant reduction in the quantity of salt produced, the total for 1906 being 1,225,465 tons, against 1,291,137 tons produced in 1905 (table 22).

TABLE 22.—*Provincial Production of Salt during 1904—1906.*

PROVINCE.	1904.	1905.	1906.
	Statute Tons.	Statute Tons.	Statute Tons.
Aden	66,007	97,727	67,535
Bengal	88	3	61
Bombay	430,409	425,090	390,535
Burma	21,387	23,132	29,847
Gwalior State	374	84	249
Madras	356,834	388,646	412,717
Northern India	282,421	342,190	312,559
Sind	13,540	14,265	11,777
TOTAL, Statute Tons .	**1,171,060**	**1,291,137**	**1,225,280**
Total, Metric Tons .	*1,188,900*	*1,311,856*	*1,244,939*

There was a greater activity in the rock-salt mines of the Punjab, and in addition to an increased output (see table 23), the extension of tunnels has proved the persistence of the two principal seams considerably beyond the area previously known with certainty.

TABLE 23.—*Production of Rock-Salt during 1904—1906.*

—	1904.	1905.	1906.
	Statute Tons.	Statute Tons.	Statute Tons.
Salt Range, Punjab	107,403	94,048	107,194
Kohát	16,664	14,897	13,436
Mandi	4,507	3,571	3,609
TOTAL, Statute Tons .	**128,574**	**112,416**	**124,239**
Total, Metric Tons .	*130,635*	*114,210*	*126,233*

During 1906 there was an increase in the quantity and value of imported salt, the amount being 512,328 tons and the value £488,127, against averages for the four years 1902—1905 of 454,832 tons and £439,071 respectively.

I don't kno[illegible] where these fi[illegible] have been [illegible] the imports [illegible] 1906-7 were [illegible] 407,949 [illegible] & average of the five yea[illegible] was 475,8[illegible] tons.

Saltpetre.

The value of the saltpetre industry is gauged most uniformly by the figures for exports. The returns for the past five years shown in table 24 indicate a gradual rise in the average value, but the industry shows no signs of real expansion.

TABLE 24.—*Exports of Saltpetre during the five years 1902—1906.*

YEAR.	Weight.	*Value.*	Value per cwt.
	Cwts.	£	Shillings.
1902	390,742	*271,867*	13·9
1903	412,593	*290,196*	14·1
1904	390,970	*266,349*	13·6
1905	313,122	*235,723*	15·1
1906	347,251	*270,547*	15·6
Average	**370,936**	**266,936**	**14·5**

The local importance of the saltpetre industry is shown by the returns for labour in Behar where most of the saltpetre is obtained. The returns for 1906 show that 50,469 workers were employed in this industry.

Tin-ore.

The output of tin-ore in South Burma has considerably increased, from 1,495 cwts., valued at £9,783, in 1905, to 1,919 cwts., valued at £13,574, in 1906. A special survey of the tin-mining industry in South Burma is being carried out by an officer of the Geological Survey. The total average daily attendance at the tin mines in the Mergui and Tavoy districts was 145 in 1905 and 141 in 1906.

III.—MINERALS OF GROUP II.

The following notes deal with the minerals for which the returns are only estimated in certain areas with fair accuracy.

Alum. The production of alum in the Mianwáli district, Punjab, has increased considerably from 7,126 cwts., valued at £2,038, in 1905, to 11,022 cwts., valued at about £4,000, in 1906. In 1904 the production amounted to only 2,580 cwts. The imports of foreign alum were slightly below those returned for 1905, amounting to 69,044 cwts., valued at £20,040.

Amber. There has been a reduction in the small value reported for the amber raised in the Myitkyina district of Upper Burma, the production for 1906 being valued at £709 although reported as 217 cwts.

Borax. No borax is produced within Indian territory, but considerable quantities are brought across the frontier from Tibet for consumption in India and for export. The export figures given in table 25 show that there has been no important change in the trade during the past five years.

TABLE 25.—*Exports of Borax during the five years 1902—1906.*

YEAR.	Weight.	*Value.*	Value per cwt.
	Cwts.	£	Shillings.
1902	5,335	*8,028*	30·1
1903	5,674	*7,797*	27·5
1904	4,246	*5,419*	25·5
1905	4,198	*5,246*	25·0
1906	4,220	*5,868*	27·2
Average	**4,735**	**6,472**	**27·2**

Building stone. The returns for building stone of most general interest are those relating to the quarrying of Vindhyan sandstone in the Mirzapur district, the production during

1906 being reported to amount to 101,745 tons, valued locally at £12,690, against 99,850 tons, valued at £12,727, in 1905. On account of its uniform and fine-grain the Mirzapur sandstone is used largely for ornamental purposes.

Copper.

There is again a small quantity of copper-ore reported as raised in the Mandalay district during 1906, amounting to 587 cwts.; but the returns for value are obviously overstated. Prospecting work has been conducted on the Singbhum copper-bearing belt. At Kodomdia near Kharsawan the zone of copper and iron pyrites, exposed by ancient outcrop workings, has been proved by diamond drilling with a fairly constant dip at depths of 400 and 1,067 feet. Between the levels 392 and 404 feet representing 8 feet thick of the lode, the 12 feet of core obtained contained 5·102 per cent. of copper and 5·8 per cent. sulphur. At a depth of 1,069 feet the cupriferous band was only about one foot in thickness with 1·825 per cent. copper.

Marble.

The production of marble at Makrana in the Jodhpur State was returned as 1,500 tons for 1906, against 1,726 tons in 1905.

Steatite.

The steatite raised in the Minbu district of Burma during 1906 amounted to 200 cwts., valued at £273, against 244 cwts., valued at £341, in 1905.

Tourmaline.

In the Ruby Mines District the tourmaline produced in 1906 amounted to 193 lbs., valued at £1,001, against 161 lbs., valued at £1,500, in 1905. An interesting report has recently been made by Mr. E. C. S. George, Deputy Commissioner of the district, on the workings for tourmaline round the small Palaung hamlet of Sanka about a mile east of Maingnin, where operations were carried on by the Chinese, according to local tradition, some 150—200 years ago. Mr. George states that, after the Chinese deserted the area, the Kachins re-started the mines about forty years ago, but the industry was again interrupted until about 1885, when more systematic operations were commenced under Pir Seinda, who contracted to conduct all mining operations until 1895. The Momeit "stone-tract" was afterwards notified by Government and regular licenses were taken up in 1899. During the past three years the amounts recovered by "tourmaline licenses" have been nearly Rs.3,000 (£200) each year. The tourmaline is found in soft, decomposed, granitic veins, which, being covered generally by a thick deposit of

jungle-clad soil, are found rather by accident than through the guidance of any superficial indications. Isolated crystals are found occasionally lying in the red soil, and men with small means find it sometimes profitable, when they have leisure, to search through the soil-cap by digging shallow pits. *Twinlons*, or vertical shafts about 4 or 5 feet square, are also put down on the chance of striking a tourmaline-bearing vein, or *kyaw*, and the owners of these *twinlons* are permitted to extend their workings underground to a radius of five fathoms from the centre of each shaft. Some of the workings extend to depths of about 100 feet, which appears to be about the limit of the miners' engineering skill. The tourmaline found is sorted into three classes: (1) *Ahtet yay*, the best light-pink rubellite, of which there are two kinds, *hteik ti*, showing well-developed basal planes, and *bé yan*, crystals terminated by rhombohedral faces, or with only a small development of the basal plane. (2) *Akka*, of a darker colour with the lower part of the crystals brown or black in colour. (3) *Sinsi* or *Arnyi*, all fragmentary crystals of any colour which are imperfect, or of a small size less than about an inch. The *sinsi* is given without charge to the buyer of the lots of the two better kinds. The best kind, *Ahtet yay*, may bring as much as Rs. 1,200 to Rs. 1,500 a viss (3·65 lbs.). The *Myaw* system, or exposure of the veins on the hill-side by hydraulic action, has also been attempted at two localities with uncertain results: this work is limited to the "rains" and is handicapped by the cost of leading the water-channels for long distances. All locally made purchases are effected by brokers, usually Shans or Shan Burmans. They in turn sell at Mandalay to purchasers for the Chinese market.

IV.—MINERAL CONCESSIONS GRANTED.

TABLE 26.—*Statement of Mineral Concessions made in Government lands during the year 1906.*

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
STAN.	Loralai .	(1) Messrs. Abdulla Asghar Ali & Co.	Coal .	Mining lease.	20	1st July 1906.	30 years.
	Quetta-Pishin.	(2) Messrs. Isaji & Sons	Do. . .	Prospecting license.	Plot A 286·501 acres, Plot B 104·6 acres, Sor Range, between miles 2 and 7.	5th December 1906.	1 year.
BENGAL.	Gaya .	(3) Jhaman Singh *alias* Jang Bahadur Singh.	Mica .	Conversion of prospecting license to mining lease	18 (about) .	The lease has not yet been executed.	10 years.
	Hazaribagh	(4) Mr. E. Lane .	Do. . .	Prospecting license.	120	12th November 1906.	1 year.
	Do. .	(5) Mr. K. E. Heyneman.	Do. . .	Do. .	280	Do. .	Do.
	Moharbhanj	(6) Messrs. B. Barooah and Patrick Gow.	Gold . .	Do. .	23,040	10th July 1906.	2 years.
	Manbhum .	(7) Sita Ram Marwari and others.	Coal . .	Mining lease.	80·561	28th August 1906.	30 years.
	Singbhum .	(8) Messrs. Hoare Miller & Co., Calcutta.	All sorts of minerals.	Exploring license.	Area between the parallels of lat. 20° 11′ N. & 22° 21′ N. & between the meridians of long. 85° 15′ E. & 85° 28′ E.	7th September 1906.	1 year.
	Sonthal Parganas.	(9) Maghu Mean .	Coal . .	Mining lease.	·137	1st October 1906.	2 years.
BOMBAY.	Dharwar .	(10) Sangli Gold Mines, Ld.	Gold .	Do. .	275·8	2nd January 1906.	30 years.
	Do. .	(11) Do. do. .	Do. . .	Do. .	588·27	Do. .	Do.
	Do. .	(12) Mr. C. H. B. Forbes.	Do. . .	Prospecting license.	1,638·3	27th January 1906.	1 year.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
BOMBAY—*contd.*	Dharwar .	(13) The Dharwar Gold Mines, Ld.	Gold .	Mining lease.	163·28	2nd April 1906.	30 years
	Do. .	(14) Mr. R. O. Ahlers (Agent for the Gold Fields of Dharwar).	Do. . .	Do. .	589·22	13th June 1906.	Do.
	Panch Mahals.	(15) F. A. H. East, Agent, Shivrajpur Syndicate, Ld., Bombay.	Manganese-ore.	Prospecting license.	401	26th October 1906.	1 year.
	Do. .	(16) Do. do. .	Mica. .	Exploring license.	150	Do. .	Do.
BURMA.	Bassein .	(17) Maung Po Mya .	Coal . .	Prospecting license.	3,200	1st September 1906.	Do.
	Bhamo .	(18) Maung Law Ku .	Precious stones.	Exploring license.	16,000	3rd January 1906.	Do.
	Do. .	(19) Htam Saing .	Do. .	Do. .	Not reported.	28th July 1906.	Do.
	Katha .	(20) Mr. J. M. Minus	Gold . .	Prospecting license.	605·44	20th January 1906.	Do
	Do. .	(21) Mr. J. A. Manyon	Coal . .	Do. .	1,350·40	16th May 1906.	D
	Do. .	(22) Maung San Ye .	Gold .	Do. .	11·20	17th September 1906.	D
	Do. .	(23) M. Baksh . .	Do. . .	Exploring license.	Not reported.	12th November 1906.	D
	Do. .	(24) Mr. J. A. Manyon	Copper, lead, and associated ores.	Do. .	2,880	21st December 1906.	D
	Magwé .	(25) Messrs. J. S. Jamal Bros. & Co.	Petroleum .	Prospecting license.	1,920	1st February 1906.	D
	Do. .	(26) Do. do. .	Do. .	Do. .	640	Do. .	D
	Do. .	(27) Do. do. .	Do. .	Do. .	640	28th March 1906.	D
	Do. .	(28) Messrs. Finlay, Fleming & Co.	Do.	Mining lease.	Blocks C, B_2, 1^a, 2^a, and part of Beme reserve at Yenangyaung.	1st May 1906.	30
	Do. .	(29) Do. do., Agents for the Burma Oil Co., Ld.	Do. .	Prospecting license (renewal).	1,280	11th October 1906.	1 y

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(30) Mr. Louis Joel .	Tin . .	Prospecting license.	307·56	19th April 1906.	1 year.
Do. .	(31) Mr. Charles Kitchin.	Do. . .	Do. .	640	25th August 1906.	Do.
Myingyan .	(32) Messrs. Finlay, Fleming & Co., Agents for the Burma Oil Co., Ld.	Petroleum .	Do. .	85	19th January 1906.	Do.
Do. .	(33) Do. do. .	Do. .	Do. .	1,280	15th September 1905.	Do.
Do. .	(34) Do. do. .	Do. .	Do. .	2,560	26th July 1906.	Do.
Do. .	(35) Do. do. .	Do. .	Do. .	3,840	10th August 1906.	Do.
Do. .	(36) Do. do. .	Do. .	Do. .	21,440	1st May 1906.	Do.
Do. .	(37) Messrs. Geo. Gillespie & Co., Agents for the Rangoon Oil Co.	Do. .	Prospecting license (renewal).	640	10th May 1906.	Do.
Myitkyina .	(38) Messrs. Diekmann Bros. & Co.	Gold .	Exploring license.	20 miles of the Uyu river from Kunhe to Kama, a village above Haungpa.	10th December 1906.	Do.
N. Shan States.	(39) Mr. F. Dietzsch, on behalf of the Burma Prospecting Syndicate, Ld.	Do. . .	Do. .	98,470·40	24th March 1906.	Do.
Do. .	(40) Mr. N. Samwell .	Silver, lead ores, and the associated minerals combined therewith.	Prospecting license.	3,200	24th September 1906.	Do.
Pakôkku	(41) Mr. H. W. Watts	Coal and petroleum.	Do. .	2,560	10th February 1906.	Do.
Do. .	(42) Messrs. Ko Ba Oh & Co.	Petroleum (renewal).	Do. .	1,280	13th March 1906.	Do.
Do. .	(43) Messrs. Finlay, Fleming & Co.	Petroleum .	Do. .	640	11th April 1906.	Do.
Do. .	(44) Do. do. .	Do. .	Do. .	640	Do. .	Do.
Do. .	(45) Do. do. .	Do. .	Do. .	1,280	12th June 1906.	Do.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.
BURMA—*contd.*	Pakôkku .	(46) Messrs. Ko Ba Oh & Co.	Petroleum .	Prospecting license.	102	6th July 1906.
	Do. .	(47) Messrs. A. S. Jamal Bros. & Co.	Do. .	Do. .	2,483	13th December 1906.
	Do. .	(48) Captain Waymouth, on behalf of Irrawaddy Flotilla Co.	Petroleum and coal.	Exploring license.	30,720	17th December 1906.
	Prome .	(49) Messrs. Finlay, Fleming & Co., Agents for the Burma Oil Co., Ld.	Petroleum	Prospecting license.	3,520	8th January 1906.
	Sagaing .	(50) Mr. C. Findlay .	Copper .	Do. .	426·66	29th May 1906.
	Shwebo .	(51) Messrs S. A. Mower, G. S. Clifford, E. S. Attia, and Mrs. Mary Vertannes	Gold, silver, and rubies.	Do. .	205·45	1st July 1906.
	S. Shan States.	(52) Maung Kyaw Zan, on behalf of Colonial Trading Co.	Mica .	Exploring license.	1,051,520	16th November 1905.
	Do. .	(53) Tamon of Heho Saya Kyi of Yaungbwe.	Silver and lead.	Prospecting license.	18	20th December 1906.
	Do. .	(54) Maung E. Maung and Moulvi Hyder Ali.	Coal .	Do. .	3,200	26th April 1906.
	Do. .	(55) Maung Thu Daw	Precious stones.	Exploring license.	252,800	27th April 1906.
	Do. .	(56) Burma Mining Syndicate.	Gold .	Prospecting license.	8·25	9th August 1905.
	Tavoy .	(57) Mr. A. G. Meinhold, Manager, Diekmann Bros.	Gold, silver, tin, copper, coal, plumbago, and precious stones.	Prospecting license (renewal).	3,744	1st December 1905.
	Do. .	(58) Mr. T. Fowle .	Do. .	Prospecting license.	32,000	26th January 1906.
	Do. .	(59) Messrs. Diekmann Bros. & Co., Ld., and Lieut.-Colonel Foss.	Gold and tin	Prospecting license (renewal of Mr. Rickett's license subsequently assigned to Col. Foss).	3,744	1st December 1905.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
BURMA—concld.	Tavoy .	(60) Mr. R. Gilfillan, on behalf of Golden Stream Syndicate.	Gold, silver, tin, copper, coal, plumbago, and precious stones.	Prospecting license (renewal).	224,000	20th September 1905.	1 year.
	Thayetmyo	(61) Messrs. A. S. Jamal Bros. & Co.	Petroleum .	Prospecting license.	640	12th January 1906.	Do.
	Do. .	(62) Messrs. Finlay, Fleming & Co., Agents for the Burma Oil Co., Ld.	Do. .	Do. .	5,760	16th January 1906.	Do.
	Do. .	(63) Messrs. A. S. Jamal Bros. & Co.	Do. .	Do. .	378	12th January 1906.	Do.
	Toungoo .	(64) Messrs. T. F. Francis, Agent for Mr. C. E. Brown.	Silver, lead, and other metals.	Prospecting license.	3,200	30th April 1906.	Do.
	Upper Chindwin.	(65) Messrs. A. S. Jamal Bros. & Co.	Petroleum .	Do. .	6,400	17th March 1906.	Do.
	Yamèthin	(66) Lin Chin Tsong .	Gold and tin	Do. .	5,120	13th October 1906.	Do.
CENTRAL PROVINCES.	Balaghat .	(67) Mr. P. Gow, Calcutta.	Bauxite .	Do. .	1,189	14th March 1906.	Do.
	Do. .	(68) Messrs C. D. Stewart & Co., Calcutta.	Do. .	Do. .	4,681	22nd February 1906.	Do.
	Do. .	(69) The Indian Manganese Company.	Manganese	Do. .	310	Do. .	Do.
	Do. .	(70) Messrs. Dutt, Burn & Co., Jubbulpore.	Do. .	Do. .	806	29th September 1906.	Do.
	Do. .	(71) Mr. P. Gow, Calcutta.	Bauxite .	Do. .	6,398	19th September 1906.	Do.
	Do. .	(72) Messrs. P. C. Dutt, Burn & Co., Jubbulpore.	Manganese and iron.	Exploring license.	5,523	16th August 1906.	Do.
	Do. .	(73) Do. do. .	Do.	Do. .	58,380	Do. .	Do.
	Do. .	(74) Mr. J. Kellerschon, Nagpore.	Manganese	Do. .	4,894	13th August 1906.	Do.
	Do. .	(75) Do. do. .	Do. .	Do. .	755	22nd August 1906.	Do.
	Do. .	(76) Messrs. Dutt, Burn & Co., Jubbulpore.	Iron and manganese.	Prospecting license.	345	22nd September 1906.	Do.
	Do. .	(77) The Central Provinces Prospecting Syndicate, Kamptee.	Manganese	Mining lease; extension of the Bharveli manganese mines.	8	13th July 1906	30 years.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
CENTRAL PROVINCES—*contd.*	Balaghat .	(78) Mr. D. Laxminarayan, Kamptee.	Manganese	Prospecting license.	236	4th July 1906.	1 year.
	Do .	(79) Do. do. .	Do. .	Do. .	36	2nd May 1906.	Do.
	Do. .	(80) Do. do. .	Do. .	Do. .	451	4th May 1906.	Do.
	Do. .	(81) Do. do. .	Do. .	Do. .	2,716	2nd May 1906.	Do.
	Do. .	(82) Central Provinces Prospecting Syndicate.	Do. .	Do. .	385	4th September 1906.	Do.
	Do. .	(83) Rai Sahib Mathura Prosad and Motilal.	Do. .	Do. .	118	6th December 1906.	Do.
	Do. .	(84) Diwan Bahadur Kastur Chand Daga.	Do. .	Do. .	660	17th December 1906.	Do.
	Do. .	(85) Do. do. .	Do. .	Do. .	1,160	Do. .	Do.
	Betul .	(86) Raja Gokuldas, Rai Bahadur Ballabhdas, Jubbulpore.	Coal and mineral ore.	Exploring license.	11,897	28th August 1906.	Do.
	Do. .	(87) Hon'ble Mr. Vithaldas Damoodhar Thakersay, J. P.	Coal and petroleum.	Prospecting license.	37,142	15th December 1906.	Do.
	Bhandara .	(88) Mr. D. Laxminarayan.	Manganese	Do. .	85	12th November 1906.	Do.
	Do. .	(89) Rai Sahib Mathura Prosad and Motilal.	Do. .	Do. .	30	Do. .	Do.
	Do. .	(90) Mr. M. Trikumdas Cooverji Bhoja.	Manganese, iron-ore, and galena.	Do. .	457	20th December 1906.	Do.
	Do. .	(91) Mr. E. G. Beckett	Manganese	Do. .	151	27th November 1906.	Do.
	Do .	(92) Rai Sahib Mathura Prosad and Motilal.	Do. .	Do. .	44	1st December 1906.	Do.
	Do. .	(93) Mr. G. M. Prichard.	Do. .	Do. .	1,828	20th December 1906.	Do.
	Do.	(94) Do. do. .	Do. .	Do. .	939	15th November 1906.	Do.
	Do. .	(95) Rai Sahib Mathura Prosad and Motilal.	Do. .	Do. .	99	24th November 1906.	Do.

Prov-ince.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
CENTRAL PROVINCES—*contd.*	Bhandara .	(96) Diwan Bahadur Kastur Chand Daga.	Manganese	Exploring license.	1,476	18th December 1906.	1 year.
	Do. .	(97) Mr. D. Laxminarayan, Kamptee.	Do. .	Prospecting license.	20	21st April 1906.	Do.
	Do. .	(98) Do. do. .	Do. .	Do. .	274	Do. .	Do.
	Do. .	(99) Do. do. .	Do. .	Do. .	301	11th June 1906.	Do.
	Do. .	(100) Mr. R. H. Richardson, Tumsar.	Do. .	Exploring license.	807	Do. .	Do.
	Do. .	(101) Mr. G. M. Prichard, Kamptee.	Do. .	Do. .	2,952	18th June 1906.	Do.
	Do. .	(102) Central India Mining Co., Ld., Kamptee.	Do. .	Prospecting license.	1,111	30th April 1906.	Do.
	Do. .	(103) Do. do. .	Do. .	Do. .	68	Do. .	Do.
	Do. .	(104) Do. do. .	Do.	Do. .	723	Do. .	Do
	Do. .	(105) Mr. D. Laxminarayan, Kamptee.	Do. .	Do. .	25	21st April 1906.	Do.
	Do. .	(106) Do. do. .	Do. .	Do. .	44	2nd January 1906.	Do.
	Do. .	(107) Rai Sahib Mathura Prosad and Motilal, Chhindwara.	Do. .	Do. .	474	18th August 1906.	Do.
	Chanda. .	(108) Messrs. Tata & Sons.	Iron . .	Mining lease	160	1st December 1906.	30 years.
	Chhindwara	(109) Ratanchand Kesrichand.	Coal . .	Prospecting license.	2,262	27th January 1906.	1 year.
	Jubbulpore	(110) Mr. Srish Chandra Roy Chowdhri, Pleader.	Gold, silver, copper, and lead.	Exploring license.	8,487	15th January 1906.	Do.
	Do. .	(111) P. C. Dutt, Esq., Barrister-at-Law.	Gold, silver, copper, lead, barytes, iron, manganese, and tin.	Do. .	6,881	Do. .	Do.
	Do. .	(112) Messrs. H. F. Cook & Son, Katni.	Aluminium, coal, iron-ore.	Do. .	2,946	29th September 1906.	Do.
	Do. .	(113) P. C. Dutt, Esq., Barrister-at-Law.	Bauxite .	Prospecting license.	219	21st June 1906.	Do.
	Do. .	(114) Mr. Srish Chandra Roy Chowdhri.	Gold, silver, copper, and lead.	Do. .	35	9th April 1906.	Do.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
CENTRAL PROVINCES—*contd.*	Jubbulpore	(115) The Jubbulpore Prospecting Syndicate.	Iron, manganese, and copper.	Exploring license.	4,588	1st June 1906.	1 year.
	Do.	(116) Do. do.	Gold, silver, copper, lead, antimony, arsenic, barytes, dolomite, limestone, zinc, and tin.	Prospecting license (renewal).	3,791	22nd February 1906.	Do.
	Do.	(117) Messrs. Burn & Co., Calcutta.	Gold, silver, copper, iron, zinc, tin, and coal.	Exploring license.	5,993	4th October 1906.	Do.
	Do.	(118) Messrs. H. F. Cook & Sons.	Gold, silver, copper, platinum, zinc, tin, lead, nickel, mercury, manganese, and diamond.	Do.	30,810	13th November 1906.	Do.
	Do.	(119) Do. do.	Gold, silver, zinc, lead, titanium, tungsten, tin, uranium, and platinum.	Do.	8,442	5th November 1906.	Do.
	Nagpur	(120) Central Provinces Prospecting Syndicate, Kamptee.	Manganese	Mining lease	45	24th May 1906.	30 yea
	Do.	(121) Mr. Trikumdas Cooverji Bhoja, Calcutta.	Do.	Prospecting license.	50	2nd May 1906.	1 year
	Do.	(122) Mr. E. G. Beckett, Kamptee.	Do.	Do.	101	13th June 1906.	Do.
	Do.	(123) Mr. G. M. Prichard, Kamptee.	Do.	Exploring license.	30	10th September 1906.	Do.
	Do.	(124) Do. do.	Do.	Do.	3,207	Do.	Do.
	Do.	(125) Mr. Trikumdas Cooverji Bhoja, Calcutta.	Do.	Prospecting license.	794	20th July 1906.	Do.
	Do.	(126) Central Provinces Prospecting Syndicate, Kamptee.	Do.	Mining lease.	17	21st August 1906.	30 ye
	Do.	(127) Do. do.	Do.	Do.	12	7th July 1906.	Do.

Province.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
CENTRAL PROVINCES—concld.	Nagpur .	(128) Mr. D. Laxminarayan, Kamptee.	Manganese	Prospecting license.	13	15th August 1906.	1 year.
	Do. .	(129) The Central India Mining Co., Ld.	Do. .	Do. .	103	7th February 1906.	Do.
	Do. .	(130) Do. do. .	Do. .	Mining lease .	170	Do. .	30 years.
	Do. .	(131) Do. do. .	Manganese and copper.	Prospecting license.	4,066	28th March 1906.	1 year.
	Do. .	(132) Mr. D. Laxminarayan, Kamptee.	Coal . .	Do. .	1,241	26th March 1906.	Do.
	Do. .	(133) Do. do. .	Manganese	Do. .	189	Do. .	Do.
	Do. .	(134) Do. do. .	Do. .	Do. .	53	27th June 1906.	Do.
	Do. .	(135) Do. do. .	Do. .	Do. .	94	21st December 1906.	Do.
	Do. .	(136) Mr. J. Kellerschon.	Do. .	Exploring license.	388	21st November 1906.	Do.
	Do. .	(137) Do. do. .	Do. .	Do. .	388	Do. .	Do.
	Do. .	(138) Do. do. .	Do. .	Do. .	859	Do. .	Do.
	Do. .	(139) Do. do. .	Do. .	Do. .	959	Do. .	Do.
	Saugor .	(140) Messrs. Kali Prasanna Mukerji and Bhagwan Das Sirvaya.	Mica, corundum, and dolomite.	Do. .	8,563	29th September 1906.	Do.
	Do. .	(141) Do. do. .	Iron-ore and other ores.	Do. .	1,130	30th October 1906.	Do.
EASTERN BENGAL AND ASSAM.	Cachar .	(142) Mr. W. Gordon Stoker.	Mineral oil and coal.	Prospecting license.	362,592	......	...
	Chittagong	(143) Messrs. Turner, Morrison & Co., Calcutta.	Coal, oil, gold or silver, iron, copper, tin, or other metals and other precious stones.	Do. .	11,520	10th July 1906.	1 year.
MADRAS.	Anantapur.	(144) Mr. H. P. Gibbs	Gold .	Do. .	4,095	25th September 1906.	Do.
	Bellary .	(145) Mr. E. D. Puzey	Do. . .	Do. .	634·87	31st July 1906.	Do.
	Do. .	(146) Mr. C. Jambon .	Minerals .	Exploring license.	4,248·96	4th August 1906.	Do.
	Do. .	(147) Mr. C. J. Greengrass.	Manganese	Prospecting license.	1,594·95	4th September 1906.	Do.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
MADRAS—*contd.*	Bellary .	(148) Mr. C. Jambon .	Manganese	Prospecting license.	2,270·81	7th September 1906.	1 year.
	Do. .	(149) Mr. W. T. Hamilton-Holmes.	Gold .	Do. .	1,920	19th December 1905.	Do.
	Do. .	(150) R. Srinivasa Rao Nayudu.	Manganese	Do. .	1,472	11th October 1906.	Do.
	Do. .	(151) F. E. Dum .	Do. .	Do. .	319	28th November 1906.	Do.
	Coimbatore	(152) Govindjee Odajee Sait.	Corundum.	Mining in patta land.	8·28	23rd November 1906.	20 years.
	Kistna .	(153) The Southern India Coal Mining Syndicate, Ld., Madras.	Coal and other minerals.	Exploring license.	184,445·27	13th November 1906.	1 year.
	Do. .	(154) P. Venkatarama Nayudu.	Mica. .	Prospecting license.	17·50	13th October 1906.	Do.
	Nellore .	(155) D. Venkata Rao	Manganese	Exploring license.	Area not fixed.	12th September 1906.	Do.
	Do. .	(156) K. Panchala Reddi.	Mica .	Prospecting license. .	25·68	17th December 1906.	Do.
	Do. .	(157) K. Kothandarami Reddi.	Do. . .	Do. .	20	Do. .	Do.
	Do. .	(158) R. Lakshminarasa Reddi.	Do. . .	Do. .	37·45	Do. .	Do.
	Do. .	(159) Do. do. .	Do. . .	Do. .	30·80	19th December 1906.	Do.
	Do. .	(160) Murlidar Chadik	Do. . .	Mining in patta land.	5	25th June 1906.	Do.
	Do. .	(161) K. Kodandarami Reddi.	Do. . .	Prospecting license.	19·16	13th September 1906.	Do.
	Do. .	(162) Y. Kelappa Chetti and S. Chinnachenchu Nayudu.	Do. . .	Mining lease extension.	185·98	14th August 1906.	30 years.
	Do. .	(163) I. Pattabhirami Reddi.	Do. . .	Prospecting license.	26·73	24th October 1906.	1 year.
	Do. .	(164) R. Lakshminarasa Reddi.	Do. . .	Do. .	10·20	24th October 1906.	Do.
	Do. .	(165) T. Venkata Reddi	Do. . .	Do. .	19·90	20th October 1906.	Do.
	Do. .	(166) Do. do. .	Do. . .	Do. .	11·60	22nd October 1906.	Do.
	Do. .	(167) Do. do. .	Do. . .	Do. .	20	Do. .	Do.
	Do. .	(168) Y. Kalappa Chetti and S. Chinnachenchu Nayudu.	Do. . .	Mining lease.	14·96	28th August 1905.	30 years.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
MADRAS—*contd.*	Nellore .	(169) M. Devarajulu Nayudu.	Mica .	Mining lease.	23	18th September 1905.	30 years.
	Do. .	(170) A Venkatachala Mudallyar.	Do. . .	Do. .	13·24	5th August 1905.	Do.
	Do.	(171) Messrs. Hali Muhammad Badsha Sahib & Co.	Do. . .	Do. .	9·65	26th September 1905.	Do.
	Do. .	(172) P. Penchala Reddi.	Do. . .	Do. .	57·62	7th October 1905.	3 years.
	Do. .	(173) K. Appayya Chetti.	Do. . .	Do. .	218·60	13th December 1905.	30 years.
	Do. .	(174) R. Rangaswami Row.	Do. . .	Do. .	100·20	22nd September 1905.	3 years.
	Do. .	(175) C. H. Jefferson	Do. . .	Mining in patta land.	5·38	30th November 1905.	20 years.
	Do. .	(176) Y. Venkatasubbia Chetti.	Do. . .	Do. .	32	7th February 1906.	Do.
	Do. .	(177) I. Pattabhirami Reddi.	Do. . .	Prospecting license.	39·32	24th February 1906.	1 year.
	Do. .	(178) I. Venkatarama Nayudu.	Do. . .	Do. .	36·33	19th February 1906.	Do.
	Do. .	(179) I. Pattabhirami Reddi.	Do. . .	Do. .	11·43	18th January 1906.	Do.
	Do. .	(180) Do. do. .	Do. . .	Do. .	18·52	24th February 1906.	Do.
	Do. .	(181) T. Venkata Reddi.	Do. . .	Do. .	12·31	2nd February 1906.	Do.
	Do. .	(182) I. Pattabhirami Reddi.	Do. . .	Do. .	23·79	23rd August 1906.	Do.
	Do. .	(183) Virjiyamma .	Do. . .	Do. .	96·40	Do. .	Do.
	Do. .	(184) P. Venkatarama Nayudu.	Do . .	Mining lease.	46·14	5th January 1906.	30 years.
	Do. .	(185) T. Venkata Reddi.	Do. . .	Exploring license.	Not fixed	4th August 1906.	1 year.
	Do. .	(186) Do. do. .	Do. . .	Prospecting license.	19·97	2nd February 1906.	Do.
	Do. .	(187) Do. do. .	Do. . .	Do. .	10·47	Do. .	Do.
	Do. .	(188) R. V. Kuppuswami Aiyar.	Do. . .	Do. .	18·85	24th January 1906.	Do.
	Do. .	(189) T. Venkata Reddi.	Do. . .	Do. .	12·21	2nd February 1906.	Do.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
MADRAS—*contd.*	Nellore .	(190) K. Adinarayana Reddi.	Mica .	Exploring license.	All unoccupied lands in the Gudur and Rampur taluks.	24th January 1906.	1 year.
	Do.	(191) Verji Jumma .	Do. . .	Prospecting license.	66·70	24th March 1906.	Do.
	Do. .	(192) I. Pattabhirami Reddi.	Do. . .	Mining lease.	109·47	Do. .	3 years.
	Do. .	(193) P. Pitchi Reddi .	Do. .	Mining in patta land.	2 30	6th May 1906.	20 years.
	Do. .	(194) K. Linga Reddi	Do. . .	Prospecting license.	34·80	23rd July 1906.	1 year.
	Do. .	(195) I. Pattabhirami Reddi.	Do. . .	Do. .	19·80	19th September 1906.	Do.
	Do. .	(196) G. Ramaswami Nayudu & Sons.	Do. . .	Mining lease.	20·70	18th May 1906.	30 years.
	Do. .	(197) R. V. Kuppuswami Aiyar.	Do. . .	Do. .	13·38	10th November 1905.	Do.
	Do. .	(198) V. Narayana Chetti.	Do. . .	Do. .	20·55	24th October 1905.	3 years.
	Do. .	(199) Haji Muhammad Badsha Sahib & Co.	Do. . .	Do. .	187·62	15th January 1906.	30 years.
	Do. .	(200) Do. do. .	Do. . .	Do. .	133·70	14th March 1906.	Do.
	Do. .	(201) A. Subba Nayudu	Do. . .	Do. .	81·26	16th March 1906.	Do.
	Do. .	(202) Do. do. .	Do. . .	Do. .	271·31	Do. .	Do.
	Do. .	(203) Muhammad Asaduddin Ahmed and Muhammad Ziuddin Ahmed.	Do. . .	Do. .	15·37	1st March 1906.	8 years.
	Do. .	(204) Haji Muhammad Badsha Sahib & Co.	Do. . .	Do. .	122·60	14th December 1905.	30 years.
	Do. .	(205) A. Subba Nayudu	Do. . .	Do. .	98·26	16th March 1906.	Do.
	Do. .	(206) Do. do. .	Do . .	Do. .	156	31st March 1906.	Do.
	Do. .	(207) Do. do. .	Do. . .	Do. .	163·8	Do. .	Do.
	Do. .	(208) Do. do. .	Do. . .	Do. .	121·70	3rd March 1906.	Do.
	Do. .	(209) R. V. Kuppuswami Aiyar.	Do. . .	Do. .	26·42	15th March 1906.	Do.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
MADRAS—*contd.*	Nellore .	(210) G. Ramaswami Nayudu & Sons.	Mica .	Mining lease.	25·90	19th April 1906.	30 years.
	Do. .	(211) B. Pattabhirami Reddi.	Do. . .	Do. .	85·90	24th February 1906.	Do.
	Do. .	(212) T. Venkata Reddi	Do. . .	Do. .	66·80	9th March 1906.	3 years.
	Do. .	(213) Haji Muhammad Badsha Sahib & Co.	Do. . .	Do. .	22·55	24th February 1906.	30 years.
	Do. .	(214) R. V. Kuppuswami Aiyar.	Do. . .	Do. .	101·13	1st December 1905.	Do.
	Do. .	(215) K. Adinarayana Reddi and I. Pattabhirami Reddi.	Do. . .	Do. .	76·12	9th February 1906.	3 years.
	Do. .	(216) K. Adinarayana Reddi.	Do. . .	Do. .	12·34	5th March 1906.	Do.
	Do. .	(217) Balarami Reddi	Do. . .	Do. .	47	16th April 1906.	Do.
	Do. .	(218) T. Sitarami Reddi	Do. . .	Do. .	61·20	17th April 1906.	Do.
	Do. .	(219) P. Kodandarami Reddi and Ramalinga Reddi.	Do. . .	Do. .	35·60	24th April 1906.	30 years.
	Do. .	(220) A. Venkitachela Mudaliyar.	Do . .	Do. .	71·70	11th May 1906.	Do.
	Do. .	(221) J. Pattabhirami Reddi.	Do. . .	Prospecting license.	12·81	28th May 1906.	1 year.
	Do. .	(222) Muhammad Khairuddin.	Do. . .	Do. .	12·30	6th April 1906.	Do.
	Do. .	(223) B. Pattabhirami Reddi.	Do. . .	Do. .	28·10	29th May 1906.	Do.
	Do. .	(224) C. H. Jefferson .	Do. . .	Do. .	20	22nd May 1906.	Do.
	Do. .	(225) R. Lakshminarasai Reddi.	Do. . .	Do. .	25·60	13th June 1906.	Do.
	Do. .	(226) A. Venkatarama Aiyar and T. Chinnaswam Iyer.	Do. . .	Do. .	48·10	30th May 1906.	3 years.
	Do. .	(227) V. Venkatasubbiah Chetti.	Do. . .	Mining in patta land.	4·50	8th June 1906.	20 years.
	Do. .	(228) K. Adinarayana Reddi.	Do. . .	Mining lease	45·34	10th May 1906.	3 years.
	Do. .	(229) R. V. Kuppuswami Iyer.	Do. . .	Prospecting license.	19	17th May 1906.	1 year.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
MADRAS—*concld.*	Nellore .	(230) Kundan Dass .	Mica . .	Mining in patta land.	1·60	30th May 1906.	20 years.
	Do. .	(231) K. Krishnaswami Mudaliyar.	Do. . .	Do. .	1·70	28th May 1906.	Do.
	Do. .	(232) T. Venkata Reddi	Do. . .	Prospecting license.	11·52	15th June 1906.	1 year.
	Do. .	(233) R. Rangaswami Row.	Do. . .	Do. .	19·75	22nd May 1906.	Do.
	Do. .	(234) R. V. Kuppuswami Iyer.	Do. . .	Do. .	24·68	17th May 1906.	Do.
	Do. .	(235) Do. do. .	Do. . .	Mining in patta land.	5	19th May 1906.	20 years.
	Do. .	(236) D. Venkata Row	Do. . .	Prospecting license.	13·50	26th June 1906.	1 year.
	Do. .	(237) Haji Muhammad Badsha Sahib & Co.	Do. . .	Mining lease.	3	26th January 1906.	5 years.
	Do. .	(238) P. Subarami Reddi.	Do. . .	Do. .	48	16th July 1906.	30 years.
	Nilgiris .	(239) Mr. F. W. F. Fletcher.	Gold . .	Prospecting license.	103·85	29th August 1906.	2 years.
	Salem .	(240) Govindji Odoji Sait.	Corundum	Do. .	1,566·61	1st April 1906.	1 year.
	Do. .	(241) The Morgan Crucible Co., Ld., Trivandrum.	Magnesite	Do. .	358·44	25th September 1905.	Do.
	Vizagapatam.	(242) Messrs. P. Macfadyen & Co.	Minerals of every description and mineral oil.	Exploring license.	254,048	4th August 1906.	Do.
	Do. .	(243) Mr. Tom Caplen, Manager, Vizianagram Mining Co.	Minerals and mineral ore.	Do. .	254,048	28th November 1906.	Do.
PUNJAB.	Attock .	(244) S. Mehdi Shah of Mirza.	Coal . .	Prospecting license.	717½	7th March 1906.	Do
	Jhelum .	(245) Rai Sahib Rocha Ram & Sons.	Do. . .	Do. .	233	21st June 1906.	Do.
	Do. .	(246) Do. do. .	Do. . .	Do. .	495	Do. .	Do.
	Mianwáli .	(247) Rai Bahadur Anup Singh & Co., represented by Sardar Lakshman Singh.	Do. . .	Mining lease.	2,876	Lease under execution.	15 years.

PROVINCE.	District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
PUNJAB—*contd.*	Pind Dadan Khan.	(248) Punjab Coal Co.	Coal . .	Prospecting license.	152	22nd April 1904.	1 year. Renewed till 21st April 1907.
	Do. .	(249) Rai Sahib Rocha Ram & Sons.	Do. . .	Do. .	256	17th November 1906.	1 year.
	Do. .	(250) Pandit Bhola Nath.	Do. . .	Do. .	120	21st December 1906.	Do.
	Do. .	(251) Do. do. .	Do. . .	Do. .	295	Do. .	Do.
	Shahpur .	(252) Rai Sahib Rocha Ram & Sons.	Do. . .	Do. .	833	23rd June 1906.	Do.

Summary.

PROVINCES.	Prospecting licenses.	Exploring licenses.	Mining leases.	Total of each Province.
Baluchistan	1	...	1	2
Bengal	3	1	3	7
Bombay	2	1	4	7
Burma	40	9	1	50
Central Provinces	46	23	6	75
Eastern Bengal and Assam	2	...	...	2
Madras	45	7	48	100
Punjab	8	...	1	9
Total for each kind and Grand Total, 1906 .	**147**	**41**	**64**	**252**
Totals for 1905 .	**115**	**44**	**30**	**189**

CLASSIFICATION OF LICENSES AND LEASES.

TABLE 27.—*Prospecting and Mining Licenses granted in Baluchistan during 1905 and 1906.*

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Loralai . .	1	20	Coal .	...	...	...
Quetta-Pishin	...	...	...	1	391·101	Coal.
TOTAL .	1	...	...	1	...	...
Mining Leases.						
Loralai . .	...	...	...	1	20	Coal.
Quetta-Pishin	2	120	Chromite and coal.	...	...	...
Zhob . .	2	160	Chromite .	...	...	...
TOTAL .	4	...	...	1	...	...

TABLE 28.—*Prospecting and Mining Licenses granted in Bengal during 1905 and 1906.*

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Darjeeling .	1	510	Any mineral, especially copper ores.	...	...	...
Hazaribagh .	...	...	...	2	400	Mica.
Moharbhanj	1	12,800	Iron-ores .	1	23,040	Gold.
TOTAL .	2	...	...	3	...	...

TABLE 28.—*Prospecting and Mining Licenses granted in Bengal during 1905 and 1906*—contd.

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Mining Leases.						
Gaya . .	...	...	...	1	18	Mica.
Manbhum .	...	...	...	1	80·561	Coal.
Sonthal Parganas.	...	...	...	1	·137	Do.
TOTAL .	0	...	...	3	...	...

TABLE 29.—*Prospecting and Mining Licenses granted during 1905 and 1905.*

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Belgaum .	2	22,997·12	Manganese	...	...	...
Dharwar .	7	5,177	Gold and manganese.	1	1,638·3	Gold.
Kanard .	1	4,992	Manganese	...	...	...
Panch Mahals	1	706·19	Do.	1	401	Manganese.
Satara . .	1	1,280	Bauxite and other minerals.	...	...	...
TOTAL .	12	...	...	2	...	...
Mining Leases.						
Belgaum .	1	...	Coal and manganese.	...	...	...
Dharwar .	...	...	...	4	1,616·57	Gold.
TOTAL .	1	...	...	4	...	...

TABLE 30.—*Prospecting and Mining Licenses granted in Burma during 1905 and 1906.*

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Akyab . .	1	255·56	Coal . .	...	...	...
Bassein . .	...	...	...	1	3,200	Coal.
Bhamo . .	1	18	Tourmaline	...	...	...
Katha . .	1	1,350·40	Coal . .	2	616·64	Gold.
Do. .	...	...	...	1	1,350·40	Coal.
Lower Chindwin.	1	12,800	Petroleum .	...	...	...
Magwé . .	1	3,200	Do. .	4	4,480	Petroleum.
Mergui . .	3	2,256·68	Tin and other minerals.	2	947·56	Tin.
Myingyan .	5	17,248	Petroleum .	6	29,845	Petroleum.
Northern Shan States.	3	15,795·2	Gold, silver, and other minerals.	1	3,200	Silver, lead, and other minerals.
Pakôkku .	...	...	...	7	8,985	Coal and petroleum.
Prome . .	1	2,560	Petroleum .	1	3,520	Petroleum.
Sagaing	...	...	...	1	426·66	Copper.
Shwebo . .	1	205·45	Gold, silver, and rubies.	1	205·45	Gold, silver, and rubies.
Southern Shan States.	..	...	...	1	18	Silver and lead.
Do. .	...	...	...	1	3,200	Coal.
Do. .	...	...	...	1	8·25	Gold.
Tavoy . .	1	224,000	Gold, silver, tin, etc.	4	263,488	Gold, silver, tin, copper, plumbago, coal, etc.
Carried over	19	...	...	34	...	

TABLE 30.—*Prospecting and Mining Licenses granted in Burma during 1905 and 1906*—contd.

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
			Prospecting Licenses—*contd.*			
Brought forward.	19	...	...	34	...	...
Thayetmyo .	1	100	Coal . .	...	...	...
Do. .	1	6,400	Petroleum .	3	6,778	Petroleum.
Toungoo .	...	...	...	1	3,200	Silver, lead, etc.
Upper Chindwin.	1	640	Copper .	...	...	...
Do. .	2	800	Coal . .	...	...	...
Do. .	...	...	...	1	6,400	Petroleum.
Yamèthin .	1	2,560	Tin and wolfram.	...	...	...
Do. .	...	...	...	1	5,120	Gold and tin.
TOTAL .	25	...	...	40	...	...
			Mining Leases.			
Magwé . .	...	...	...	1	...	Petroleum.
Mandalay .	1	272·2	Precious stones and marble.	...	...	...
Northern Shan States.	1	2,457·60	Gold .	...	...	...
TOTAL .	2	...	...	1	...	...

TABLE 31.—*Prospecting and Mining Licenses granted in the Central Provinces during 1905 and 1906.*

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
			Prospecting Licenses.			
Balaghat .	2	458	Manganese	11	7,223	Manganese and iron.
Do. .	...	...	...	3	12,268	Bauxite.
Betul . .	...	...	...	1	37,142	Coal and petroleum.
Bhandara .	4	12,099	Manganese	17	6,673	Manganese, iron-ore, and galena.
Do. .	1	52	Asbestos .	...	...	...
Chanda .	2	12,932	Coal . .	...	...	...
Chhindwara .	8	50,036	Do. . .	1	2,262	Coal.
Do. .	6	8,260	Manganese	...	...	...
Jubbulpore .	1	13,137	Manganese and iron.	...	...	...
Do. .	3	11,403	Gold, silver, etc.	2	3,826	Gold, silver, etc.
Do. .	1	447	Talc and dolomite.	...	...	...
Do. .	...	...	...	1	219	Bauxite.
Nagpur .	1	2,287	Manganese	9	5,463	Manganese and copper.
Do. .	...	...	...	1	1,241	Coal.
Narsinghpur .	1	76	Gold, silver, etc.	...	...	...
Sambalpur .	1	2,037·11	Do. .	...	...	...
TOTAL .	31	...	...	46	...	...

TABLE 31.—*Prospecting and Mining Licenses granted in the Central Provinces during 1905 and 1906*—contd.

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Mining Leases.						
Balaghat .	...	...	...	1	8	Manganese.
Bhandara .	1	222	Manganese	...	...	...
Chanda . .	...	...	...	1	160	Iron.
Chhindwara .	1	3,827	Manganese	...	...	...
Jubbulpore .	1	9	Iron stone .	...	...	...
Nagpur .	2	126·47	Manganese	4	244	Manganese.
TOTAL .	5	...	...	6	...	...

TABLE 32.—*Prospecting Licenses granted in Eastern Bengal and Assam during 1905 and 1906.*

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Cachar . .	...	...	...	1	362,592	Mineral oil and coal.
Chittagong .	...	...	...	1	11,520	Coal, oil, gold, etc.
Khasi and Jaintia Hills	1	640	Coal and oil	...	...	...
TOTAL .	1	...	...	2	...	...

TABLE 33.—*Prospecting and Mining Licenses granted in Madras during 1905 and 1906.*

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
Prospecting Licenses.						
Anantapur	4	3,072	Gold	1	4,095	Gold.
Bellary	1	143·46	Do.	2	2,554·87	Do.
Do.	1	43·76	Manganese	4	5,656·76	Manganese.
Chingleput	1	6,835·20	Coal, etc.	...	...	...
Coimbatore	5	138	Corundum	...	...	...
Do.	2	530	Gold	...	...	...
Guntur	1	720	Copper	...	...	...
Nellore	15	578·55	Mica	36	886·38	Mica.
Nilgiris	1	103·85	Gold	1	103·85	Gold.
Salem	...	...	...	1	1,566·61	Corundum.
Do.	...	...	...	1	358·44	Magnesite.
TOTAL	31	...	...	46	...	...
Mining Leases.						
Coimbatore	...	...	...	1	8·28	Corundum.
Nellore	16	663·26	Mica	46	2,971·59	Mica.
North Arcot	1	10·86	Corundum	...	...	...
TOTAL	17	...	...	47	...	...

TABLE 34.—*Prospecting and Mining Licenses granted in the Punjab during 1905 and 1906.*

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
			Prospecting Licenses.			
Attock . .	3	1,078·75	Coal . .	1	717·25	Coal.
Jhelum . .	...	...	...	2	728	Do.
Pind Dadan Khan.	...	...	...	4	823	Do.
Shahpur .	2	670	Coal . .	1	823	Do.
TOTAL .	5	...	...	8	...	...
			Mining Leases.			
Mianwáli .	...	...	...	1	2,876	Coal.
Shahpur .	1	1,737	Coal . .	...	...	...
TOTAL .	1	..	...	1	...	...

TABLE 35.—*Prospecting Licenses granted in the United Provinces during 1905 and 1906.*

DISTRICT.	1905.			1906.		
	No.	Area. Acres.	Mineral.	No.	Area. Acres.	Mineral.
			Prospecting Licenses.			
Almora . .	2	2,075·53	Copper .	...	...	...
Garhwal .	4	3,195·70	Do. .	...	...	...
Do. .	1	1	Asbestos .	...	...	...
TOTAL .	7	...	...	0	...	...

TABLE 36.—*Summary of Concessions granted in Government lands during the ten years 1897 to 1906.*

YEAR.	Mining and Prospecting Licenses.	Exploring Licenses.	TOTAL.
1897	52	4	56
1898	85	1	86
1899	47	13	60
1900	61	11	72
1901	89	15	104
1902	89	16	105
1903	84	16	100
1904	125	26	151
1905	145	44	189
1906	211	41	252

THE AMMONITES OF THE BAGH BEDS. BY ERNEST W. VREDENBURG, A.R.S.M., A.R.C.S., F.G.S. (With Plates 14—17.)

INTRODUCTION.

THE Bagh beds is the name that has been given to some marine cretaceous strata extending up the valley of the Narbada from the neighbourhood of the plains of Gujrat to Barwaha some 240 miles from the sea-coast, when they give place to strata of fluviatile origin known as the Lameta formation. The total thickness of these interesting beds is usually insignificant, and they owe their preservation to a protective covering of basalt flows of the Deccan trap.[1] Like the Utatur beds of Southern India, they are related to the marine invasion which, in many parts of the world, marked the commencement of the Cenomanian. The only fossils from the Bagh beds that have been described and figured are the Echinoids. They include: *Cidaris namadicus* Duncan, *Salenia Fraasi* Cotteau, *Cyphosoma cenomanense* Cotteau, *Orthopsis indicus* Duncan, *Echinobrissus Goybeti* Cotteau, *Nucleolites similis* d'Orbigny, *Hemiaster cenomanensis* Cotteau, *Hemiaster similis* d'Orbigny, and were regarded by Duncan as Cenomanian in age.[2] Fossils of other zoological groups also occur, but were not critically examined.

The collections including the above fossils had been gathered partly in 1857 by Keatinge who, the year previous, had discovered the Bagh beds and recognised their cretaceous age, and by Blackwell; partly by W. T. Blanford in 1863 to 1864; and partly by P. N. Bose who between 1880 and 1883 re-visited the Bagh beds. Bose recognised three principal fossiliferous subdivisions named in ascending order the nodular limestone, the Deola and Chirákhán marl, and the coralline limestone, respectively about forty, ten, and

[1] The most complete descriptions of the Bagh beds are those by W. T. Blanford, *Mem. G. S. I.*, Vol. VI, part 3 (1869), and by P. N. Bose, *Mem. G. S. I.*, Vol. XXI, part 1 (1884).

[2] *Quart. Journ. Geol. Soc.*, XXI, p. 349 (1865); *Rec., G. S. I.*, XX, p. 81 (18 7).

thirty feet in thickness. The middle subdivision is the most fossiliferous. The fauna of the other two differs mainly by the absence of some of the fossils: the majority of those that occur are also present in the Deola and Chirákhán marl, and the three subdivisions cannot be regarded as distinct palæontological zones, but merely as three successive facies of a single stage. Mr. Bose's collections are far more extensive than those gathered by his predecessors, and some preliminary determinations of the fossils given on the authority of Dr. Feistmantel were published in his account of the Bagh beds. In most cases they require confirmation by a closer study than was practicable at the time. The state of preservation of most of the gastropods and bivalves is unsatisfactory. The chief interest of Mr. Bose's collections lies in the discovery of ammonites, which, in the collections gathered by his predecessors, were represented only by a few undeterminable fragments. One species was regarded as identical with *Placenticeras tamulicum* Kossmat[1] (wrongly united by Stoliczka with *Placenticeras Guadaloupæ* Roemer = *Pl. syrtale* Morton). Though distinctly related to *Placenticeras tamulicum*, the Bagh form, on closer examination, is found to be specifically different, and will be described below as *Placenticeras Mintoi*. This is the only common ammonite in Bose's collection and many of the specimens are in a good state of preservation. They are mostly from the nodular limestone with the exception of a few specimens from the Deola and Chirákhán marl identical in all their characters with those from the underlying limestone.

In addition to the *Placenticeras* there are two remarkable species, also from the nodular limestone, each of which is represented by a solitary fragment. They belong to the same group of forms as *Placenticeras*, but differ from it generically, and do not appear to correspond exactly with any generic type that I am aware of. I have therefore proposed a new generic name *Namadoceras* to include both these species.

Since none of the three species of ammonites so far discovered correspond with any forms described from other localities, they do not help in determining the exact age of the Bagh beds with any further degree of approximation than arrived at by Duncan from a study of the

[1] The species is attributed by Kossmat to H. F. Blanford, but, as in the case of *Ammonites madraspatanus*, Blanford's name published without figure or description is nothing but a *nomen nudum*. The two species can with better justice be attributed respectively to Kossmat and Stoliczka.

Echinoids. *Placenticeras Mintoi* belongs to a group of forms ranging from the Gault to the Lower Senonian, and its presence is therefore not inconsistent with the attribution of the Bagh beds to the Cenomanian.

Genus: PLACENTICERAS Meek, 1870.

Discoidal ammonites with rather small umbilicus; shell smooth, or ornamented with spirally disposed knobs, or falciform ribs, or both; section of whorls wedge-shaped, with bevelled keel. Suture uniformly frilled by more or less pronounced marginal inflections; external saddle consisting of three sub-equal subsidiary saddles originating by subdivision of the first lateral lobe; lateral saddles variously subdivided, and auxiliary series moderately developed. Gault to Campanian. .

PLACENTICERAS MINTOI nov. spec. Pls. 14, 15.

Description.—*Placenticeras* of the group of *Pl. Fritschi*, with whorls usually very convex, never greatly compressed, with a fairly broad bevelled keel limited by angular margins except in the body whorl of adult specimens when the siphonal area tends to become smoothly rounded; umbilicus deep and rather narrow; strongly projecting ornamentation consisting of three series of knobs, the coarser of which closely follow the margin of the umbilicus, the next series situated at about two-thirds of the distance from the umbilical suture to the siphonal margin, and nearly or quite as pronounced as the inner series, but usually of more elongated outline, the last series less pronounced, much more elongated, and alternating along the angular margins on either side of the siphonal keel. The knobs of the inner two series do not alternate regularly on both sides of the shell, but are not symmetrically disposed. The relative number of knobs constituting the three series are in the proportion of about three to four to six. The total number of the umbilical knobs in one whorl averages six or seven. Body chamber occupying about two-thirds of the last volution. The buccal aperture is sinuous, with rounded siphonal and lateral crests.[1]

Sutural elements entirely frilled with fine but mostly shallow marginals. Of the three subsidiary saddles, constituting the external saddle,

[1] This appears to be the first specimen of *Placenticeras* yet discovered that shows the shape of the buccal aperture.

the outermost is larger and more ramified than the next one, the third being very broad. The lobe that intervenes between the first and second saddles following the termination of the first lateral lobe is appreciably shallower, even in adult specimens, than the one separating the two following saddles. It is evident that the first and second of these saddles are subdivisions of the true first lateral saddle. This character distinguishes the sutural line of *Placenticeras Mintoi* from that of *Pl. tamulicum.*

Dimensions.—The only specimen in which the body whorl is complete (Pl. 14, fig. 1) measures 130 millimetres in diameter, the greatest thickness being 37 millimetres for a radius of 67 millimetres, avoiding the knobs in the thickness measurement. The species grew to a much larger size than is shown in the above figures. Another specimen is entirely chambered up to a radius of 70 millimetres and must have been at least 180 millimetres in diameter. The sutures of this specimen are shown on Pl. 14, fig. 2. At a radius of 69 millimetres, the thickness is 40 millimetres, the ratio being about the same as in the previous specimen. The shape of the section of this specimen is shown on Pl. 15, fig. 2. Both the above-mentioned individuals belong to the more compressed variety of the species, the degree of flattening never amounting to what one observes in certain specimens of *Placenticeras tamulicum.* In other specimens the ratio of thickness to radius varies from $\frac{3}{6}$ to $\frac{3}{4}$. The greatest thickness is close to the umbilical suture. (See the sections represented on Pl. 15.) The section of an inflated specimen, Pl. 15, fig. 3, shows that at a diameter of 21 millimetres this ammonite exhibits the compressed shape common to all species of *Placenticeras* in their early stages.

The ratio between the height of the whorls (measured from the keel of the previous whorl), and the corresponding radius, is about $\frac{6}{11}$, and is the same both for compressed and inflated varieties.

Certain specimens, such as the one shown on Pl. 15, figs. 1, *1a*, assume the adult characteristic of a rounded siphonal margin at a comparatively small size. They seem therefore to be full-grown or nearly so. These differences of size, observed in many species of ammonites, are perhaps a sexual character, as has already been suggested by several naturalists.

Development of suture.—The clearness with which the sutural line exhibits the mode of origin of its elements distinguishes this form from other allied species, none of which, with the exception of

Placenticeras pacificum, preserve the individuality of the first lateral saddle in so pronounced a manner. Mr. Bose's collection includes numerous specimens of all sizes, and in the smaller ones the individuality of the original elements is still more pronounced. The specimens of *Placenticeras tamulicum* in the Indian Museum are all of large size, so that it is not possible to compare this feature at its earlier stages with *Placenticeras Mintoi.* The latter in specimens of small size exhibits some very interesting and instructive features, clearly showing the manner in which the complex subdivisions originate: at a diameter of as much as 72 millimetres, the outermost adventitious lobe is of much smaller size than the two following ones, a character which persists in the adults of the Gault and Cenomanian species *Placenticeras Ebrayi* and *Pl. saadense;* the third adventitious saddle appears as a mere indentation of the first lateral lobe. The derivation from the true first lateral saddle of the two inflections simulating a first and second lateral saddle which is indicated even in the adult by the relatively small size of the lobe between them is absolutely evident in small specimens of the size just referred to where the lobe between them is a mere notch at the summit of the massive first lateral saddle (Pl. 14, fig. 3).

But for the inequality that subsists in the lateral elements in the adult, the suture closely resembles that of *Placenticeras tamulicum* Although the inequalities of the lateral inflections in young specimens of *Placenticeras Mintoi* tend to become equalised as the shell grows up, yet the relatively small size of the adventitious lobe subdividing the first lateral saddle remains perfectly appreciable even at a radius of 65 millimetres (Pl. 14, fig. 2), while nothing of the sort can be detected in specimens of *Placenticeras tamulicum* of the same dimension, or even down to a radius of 45 millimetres, the smallest size at which I have been able to observe clearly the sutures of the south Indian species. Apart from this detail, the sutures in adult specimens of both species are almost identical. The third adventitious saddle is usually more slender in *Placenticeras tamulicum* than in *Pl. Mintoi;* yet in certain individuals of the South Indian form, such as the large specimen represented on Pl. XLVII of Stoliczka's work on the cretaceous ammonites of Southern India (the suture of which is not figured), it has the same broad shape as is usually observed in the Bagh species.

This interesting Indian ammonite is dedicated to His Excellency the Earl of Minto, Viceroy of India.

Localities and geological horizon.—This ammonite occurs in great abundance in the nodular limestone, where it has been collected by Mr. Bose at a large number of localities. It is found somewhat more sparingly in the overlying Deola and Chirákhán marl, the specimens from this bed being in every respect similar to those of the nodular limestone.

Relation to other species.—This species, although related to *Placenticeras tamulicum*, differs from it in its usually much stouter shape and especially in its ornamentation. It has more convex whorls than any other *Placenticeras* yet described. The protuberances of the second row are much more pronounced than in the South Indian species, and those of the third row, along the keel, much fewer.

All the above characters are variable in both species, yet even at their extreme limits there is no possible ambiguity, especially as the several characters do not vary simultaneously in the same direction: for instance, although the thickest specimens of *Placenticeras tamulicum* may be as massive as the thinnest ones of *Pl. Mintoi*, the increase in thickness is not accompanied by a reduction in the number of protuberances, or by an increase of their dimensions, or any other approach towards the characters of *Placenticeras Mintoi*. The variations in the suture of *Placenticeras tamulicum* are quite independent of the shape of the shell.

The irregularity of the progression in size of the lateral lobes and saddles differs from that figured for other species. In the degree of marginal frilling of the inflections, it is related to *Placenticeras tamulicum* and *Pl. Fritschi*. The small size of the inflection simulating a first lateral lobe, especially in young specimens where it appears as a mere indentation of the first lateral saddle, clearly shows the mode of origin of the three inflections which, in most species of *Placenticeras*, seem to represent the two lateral and first auxiliary saddle, while in reality they only represent the two lateral ones. It so happens, however, that in the one species whose ontogeny has been completely studied, *Placenticeras californicum* (Perrin Smith, *Proceedings of the California Academy of Sciences*, 3rd series, *Geology*, I, p. 181, 1900), the first lateral saddle never loses its individuality, still less even than in *Placenticeras Mintoi*.

Grouping of species.—Up to the present, there have been described 19 species of *Placenticeras* which can be grouped in four sections. They are enumerated and briefly diagnosed in the following list.

SECTION I.

1. PLACENTICERAS MEEKI Böhm, 1898.

Zeitschrift der deutschen geologischen Gesellschaft, L, p. 200. Meek, Invertebrate Cretaceous and Tertiary Fossils of the Upper Missouri Country, p. 465, Pl. XXIV, fig. 2 (1876).

Greatly compressed, with narrow keel; smooth; suture extremely ramified, more so than in any other species. Campanian (Fort Pierre group).

2. PLACENTICERAS PLACENTA Dekay, 1828.

Whitfield, Gasteropoda and Cephalopoda of the Raritan Clays and Greensand Marls of New Jersey, p. 255, Pls. XI, XLI, figs. 1, 2 (1892).

Compressed; smooth, except for a row of umbilical knobs; suture greatly ramified. Campanian.

3. PLACENTICERAS KHARASMENSE Romanofsky, 1884.

Materials for the Geology of Turkestan, II, p. 134, Pls. II, III, fig. 1.

Compressed; smooth, except for a row of weakly developed umbilical knobs; sutural inflections very finely frilled and deeply ramified. Probably Campanian.

So far as can be made out from published figures, the distinctness of this species from *Pl. placenta* is doubtful.

4. PLACENTICERAS BIDORSATUM Roemer, 1841.

Schlüter, Cephalopoden der oberen deutschen Kreide, *Palæontographica*, XXI, p. 51, Pl. XV, figs. 6-8 (1872).

Greatly compressed; keel very narrow; smooth, except for a row of knobs along the external shoulders of adults; sutural inflections much ramified. Campanian.

5. PLACENTICERAS INTERCALARE Meek, 1876.[1]

Loc. cit., p. 468, Pl. XXIII.

[1] If, as suggested by Whitfield and by Böhm, one of the two forms described by Meek from the Fort Pierre group is to be specifically separated from the original *Pl. placenta*, the second one can no longer be considered as a variety, but must also be regarded as a distinct species. By their sutural lines, the two Fort Pierre forms are much more nearly related to one another than to *Pl. placenta* of New Jersey. If the smooth-shelled form, Pl. XXIV of Meek's monograph, be separated from *Pl. placenta* under the name of *Pl. Meeki* Böhm, there is no reason for maintaining the tuberculated form *intercalare*, Pl. XXIII, as a variety of *Pl. placenta* rather than of *Pl. Meeki*.

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The irregularity of the progression in size of the lateral lobes and saddles differs from that figured for other species. In the degree of marginal frilling of the inflections, it is related to *Placenticeras tamulicum* and *Pl. Fritschi*. The small size of the inflection simulating a first lateral lobe, especially in young specimens where it appears as a mere indentation of the first lateral saddle, clearly shows the mode of origin of the three inflections which, in most species of *Placenticeras*, seem to represent the two lateral and first auxiliary saddle, while in reality they only represent the two lateral ones. It so happens, however, that in the one species whose ontogeny has been completely studied, *Placenticeras californicum* (Perrin Smith, *Proceedings of the California Academy of Sciences*, 3rd series, *Geology*, I, p. 181, 1900), the first lateral saddle never loses its individuality, still less even than in *Placenticeras Mintoi*.

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Compressed, with narrow keel; rather numerous small, not very prominent knobs, disposed in three rows, one along the umbilical and one along the external margin, and one intermediate one; suture greatly ramified, closely resembling that of *Pl. Meeki.* Campanian (Fort Pierre group).

6. PLACENTICERAS SUBTILISTRIATUM Jimbo, 1894.

Beiträge zur kentniss der Fauna der Kreideformation von Hokkaido. *Palaeontologische Abhandlungen*, VI, p. 171, Pl. XVII, fig. 1, 1894.

Described from immature specimens of a size at which the characters cannot be depended upon for specific distinction. Considering that the suture is described as complicated and deeply ramified even at the immature stage of the specimens, it is probable that the species belongs to the group of *Placenticeras placenta.* Exact horizon unknown.

7. PLACENTICERAS TELIFER Morton, 1834.

Whitfield, *loc. cit.*, p. 257, Pl. XLI, figs. 10, 11.

Fragments too incomplete for diagnosis; all that can be recognised is that the suture is greatly frilled and ramified, and that the species attained large dimensions. It perhaps belongs to the group of *Placenticeras placenta*, and like it is found in New Jersey, but probably at a lower horizon, which may be the base of the Campanian, or the summit of the Santonian.

SECTION II.

8. PLACENTICERAS SYRTALE Morton, 1834.

De Grossouvre, Les Ammonites de la Craie supérieure, p. 128, Pl. V, fig. 3; Pl. VI, figs. 1, 2; Pl. VII, fig. 1; Pl. VIII, fig. 1 (1894).

Whorls usually thick, keel relatively broad; at intermediate stages of growth there are three series of prominent knobs or denticulations, external, umbilical, and intermediate, but the two inner series gradually move outwards as the specimens approach maturity, till the denticulations along the keel become completely displaced by the knobs of the second row. The three adventitious saddles constituting the compound external saddle gradually decrease in size as they recede from the siphonal margin; the gradation continues regularly through the succeeding lateral and auxiliary inflections, so that the original irregularities of progression in size of the sutural elements are almost entirely

obliterated. Inflections moderately frilled, and very little ramified, Santonian.

SECTION III.

9. PLACENTICERAS PRUDHOMMEI Peron, 1897.

Les Ammonites du Crétacé Supérieur de l'Algérie, *Mém. Soc. Géol. de Fr.*, No. 17, p. 56, Pl. IX, figs. 3-7; Pl. XVII, fig. 8.

Compressed; keel rather narrow; umbilical and marginal tubercles distinct, intermediate ones indistinct. The characters of the suture cannot be clearly made out, the one figured belonging apparently to a immature specimen. Lower Senonian.

10. PLACENTICERAS CALIFORNICUM Anderson, 1900.

Perrin Smith, The Development and Phylogeny of *Placenticeras*, *Proc. Cal. Acad. of Sc.* (3rd ser.), *Geology*, Vol. I, p. 203, Pl. XXV, figs. 1-8; Pl. XXVIII, fig. 6.

Rather compressed; keel fairly broad; sides ornamented with rough sigmoidal ribs; two series of knobs, coarse ones round the umbilical margin, and small elongated ones along the margin of the keel. Details of the suture have not been published, but judging from the description, it is related to that of *Pl. tamulicum* and *Pl. pacificum*. Lower Senonian (Chico = Trichinopoli).

11. PLACENTICERAS PACIFICUM Perrin Smith, 1900.

Loc. cit., p. 207, Pl. XXIV, figs. 1-21; Pl. XXV, figs. 9-11; Pl. XXVI; Pl. XXVII, figs. 1-13; Pl. XXVIII, figs. 1-5.

Compressed; keel moderately narrow; sides ornamented with falciform ribs; umbilical and external knobs small, but distinct, intermediate ones indistinct; sutural elements finely frilled, and with deep ramifications which are neither so numerous nor so regularly disposed as in the *Pl. placenta* group; individuality of the first lateral saddle very distinct. Lower Senonian (Chico = Trichinopoli).

12. PLACENTICERAS TAMULICUM Kossmat, 1895.

Untersuchungen über die südindische Kreideformation, p. 78, Pl. VIII, fig. 1.

Thickness usually moderate, but very variable; keel usually moderately broad; pronounced umbilical knobs, and rather numerous pronounced denticulations on the margins of the keel; the intermediate series of swellings inconspicuous; suture moderately frilled and ramified. Lower Senonian (Trichinopoli).

13. PLACENTICERAS FRITSCHI de Grossouvre, 1894.

Les Ammonites de la Craie Supérieure, p. 124, Pl. V, figs. 1, 2.

Moderately compressed; keel relatively broad; closely similar to *Pl. tamulicum*, except that the angular margins of the keel are smooth. Coniacian.

14. PLACENTICERAS MEMORIA SCHLOENBACHI Laube and Bruder, 1887.

Ammoniten des böhmischen Kreide, *Palæontographica*, Vol. XXI, p. 221, Pl. XXIII.

Much compressed; keel very narrow; only the umbilical knobs developed; suture resembles that of the two preceding species. Turonian.

15. PLACENTICERAS SAADENSE Thomas and Peron, 1889-90.

Description des mollusques fossiles des terrains crétacés de la région sud des hauts-plateaux de la Tunisie, p. 19, Pl. XVI, figs. 3-7.

Compressed; apparently smooth; the suture, so far as can be made out, is moderately frilled and ramified, and has unequal inflections betraying their mode of origin even in the adult; the outermost adventitious lobe is rather shallow as in *Pl. Ebrayi*, and in immature specimens of *Pl. Mintoi*. Cenomanian.

16. PLACENTICERAS MINTOI Vredenburg, 1907.

Whorls very thick; keel rather broad; three series of pronounced, widely spaced protuberances, along the margins of the umbilicus and of the keel, and along the external shoulders; suture moderately frilled and ramified; unequal lobes in the lateral series, plainly showing that the first lateral saddle consists of two subsidiary saddles. Cenomanian.

17. PLACENTICERAS UHLIGI Choffat, 1886.

Recueil d'études paléontologiques sur la faune crétacique du Portugal, p. 4, Pl. II, figs. 3-5.

Shell ornamented with falciform ribs and with tubercles along the margins of the umbilicus and keel; sutures moderately frilled and ramified.[1]

[1] I have not had access to the original description of the species; the characters here given are incidenta y mentioned by Thomas and Peron in the description of *Pl. saadense*.

18. PLACENTICERAS EBRAYI de Loriol, 1882.

Études sur la faune des couches du Gault de Cosne (Nièvre), p. 7, Pl. I., *Mém. Soc. Pal. Suisse,* Vol. IX, part 2.

Whorls moderately thick; keel moderately wide; four rows of tubercles: along the margins of the umbilicus and keel, and two intermediate series; sutural inflections moderately frilled and ramified; the outermost adventitious lobe, even in very large specimens, is shallow as in *Pl. saadense* and in immature specimens of *Pl. Mintoi.* Gault.

SECTION IV.

19. PLACENTICERAS WARTHI Kossmat, 1895.

Loc. cit., p. 176, Pl. VI, fig. 8.

Compressed; smooth; outermost subsidiary saddle split into two portions by a deep adventitious lobe, so that the external saddle appears divided into four portions instead of three; the suture has numerous inflections, but is very slightly frilled, the summit of the saddles being almost devoid of marginals with the exception of a deep narrow median notch. Gault (Maravatur beds).

By grouping the species as proposed in the above list, the first section might be distinguished as the group of *Placenticeras placenta,* characterised by compressed shells with a very narrow keel, delicate or obsolete ornamentation, and an extremely frilled and ramified suture. The species of this group are very closely related to one another. They appear to be restricted to the Campanian.

The second section including *Placenticeras syrtale* and its numerous varieties is characterised by prominent tubercles which gradually travel outwards as the shell grows larger, and by a sutural line remarkable for the great sameness of successive inflections, all of which are almost devoid of deep ramifications. The ammonites of this section belong to the Santonian.

The third section, including the greatest number of species, may be called the group of *Placenticeras Fritschi.* The ammonites of this group have variously ornamented shells of variable thickness, the knobs occupying the same relative position at all stages of growth, the sutural line moderately frilled and ramified, with inflections of irregularly progressing dimensions. They range from the Gault to the Lower Senonian.

The fourth section only includes the aberrant *Placenticeras Warthi* with smooth compressed shell, and a sutural line which is greatly subdivided but scarcely frilled or ramified. The mode of origin of the adventitious inflections which can be distinctly traced, even in the adult, agrees with what is observed in other species, and clearly shows that it is a normal *Placenticeras* in spite of its aberrant characters. Its age is Albian.

The following table gives the distribution in time of the various species so far as is known :—

		Gault.	Cenomanian.	Turonian.	Lower Senonian.	Campanian.
I	*Pl. Meeki* Böhm	......	......	......	......	——
	„ *placenta* Dekay	......	......	......	......	——
	„ *kharasmense* Romanofsky . .	......	......	......	......	— ? —
	„ *bidorsatum* Roemer . . .	......	......	......	......	——
	„ *intercalare* Meek . . .	......	......	......	......	——
	„ *telifer* Morton	......	......	......	... —?	—
II	„ *syrtale* Morton	......	......	......	——	
III	„ *Prudhommei* Peron . . .	......	......	......	——	
	„ *californicum* Anderson . .	......	......	......	——	
	„ *pacificum* P. Smith . . .	......	......	......	——	
	„ *tamulicum* Kossmat . . .	......	......	......	——	
	„ *Fritschi* de Grossouvre . .	......	......	......	——	
	„ *mem. Schloenbachi* Laube and Bruder.	......	......	——		
	„ *saadense* Thomas and Peron . .	......	——			
	„ *Mintoi* Vredenburg . . .	......	——			
	„ *Uhligi* Choffat	...——	—			
	„ *Ebrayi* de Loriol	——				
IV	„ *Warthi* Kossmat	——				

It will be noticed that the species of the oldest group, that is, *Placenticeras Warthi*, exhibits the simplest outlines of sutural inflections, while in the newest group, that of *Pl. placenta*, they are extremely ramified; this is in accordance with the order usually observed in the development of other genera of ammonites. The generality of this law amongst the ammonites appears to indicate that each genus started with a relatively thick-shelled form succeeded by gradually thinner-shelled species. Since the degree of complexity of the sutures is obviously correlated with the delicacy of the shell, the manner in which this character is taken to indicate progress or regression is scarcely justified, considering that it cannot have borne any relation to the degree of complexity of the organisation.

Genus: NAMADOCERAS gen. nov.

Definition.—Smooth ammonites with wedge-shaped acutely keeled whorls, each of which completely encloses the previous one, leaving a funnel-shaped umbilical depression; sutural line finely frilled throughout its entire length, consisting of a broad external saddle divided into two main portions by a deep adventitious lobe, followed by a moderately developed lateral and auxiliary series of gradually dwindling marginally frilled inflections.

Owing to the fragmentary condition of the specimens, nothing is known regarding the shape and size of the body chamber.

Relation to other genera.—This type is somewhat of a connecting link between the genera *Placenticeras* and *Sphenodiscus*, though not intermediate between them. The shape is that of *Sphenodiscus*, but the suture recalls that of *Placenticeras*, differing, however, from both these genera owing to the subdivision of the compound external saddle into two principal masses instead of three. The resemblance of the sutural line to that of *Placenticeras* is especially marked in one of the two species, the one which I have named *Namadoceras Scindiæ*, where the more external of the two masses constituting the external saddle is itself subdivided in such a manner as to suggest a tripartite subdivision of the whole lobe not unlike that observed in *Placenticeras*. Only if the lobe be thus regarded as tripartite, the middle subdivision is of insignificant size as compared with its development in all the species belonging to the remarkably homogeneous genus *Placenticeras*;

while the same interpretation removes it still further from the characteristic Senonian forms of *Sphenodiscus*, in which the middle adventitious saddle is always as large or larger than one or other of its fellows. In the Turonian *Sphenodiscus Requieni* d'Orbigny, the second adventitious saddle is small, but still the suture differs considerably from that of *Namadoceras*, owing to the much simpler outline of the saddles, especially in the lateral and auxiliary series.

Apart from the differently constituted external saddle, the general appearance of the suture recalls that of *Placenticeras*. The marginal inflections are very similar, and the lobes and saddles are arranged very similarly as regards shape and disposition. The absence of knobs and the sharp non-bevelled keel produce an external appearance different from that of *Placenticeras*, but analogous to that of *Sphenodiscus*.

With regard to the suture, in addition to the different constitution of the external saddle, *Namadoceras* is distinguished from *Sphenodiscus* by its less complex auxiliary series. This smaller development of the auxiliary series and the greater development of marginals round the saddles distinguishes it from *Indoceras* which, like *Namadoceras*, has a bipartite external saddle.

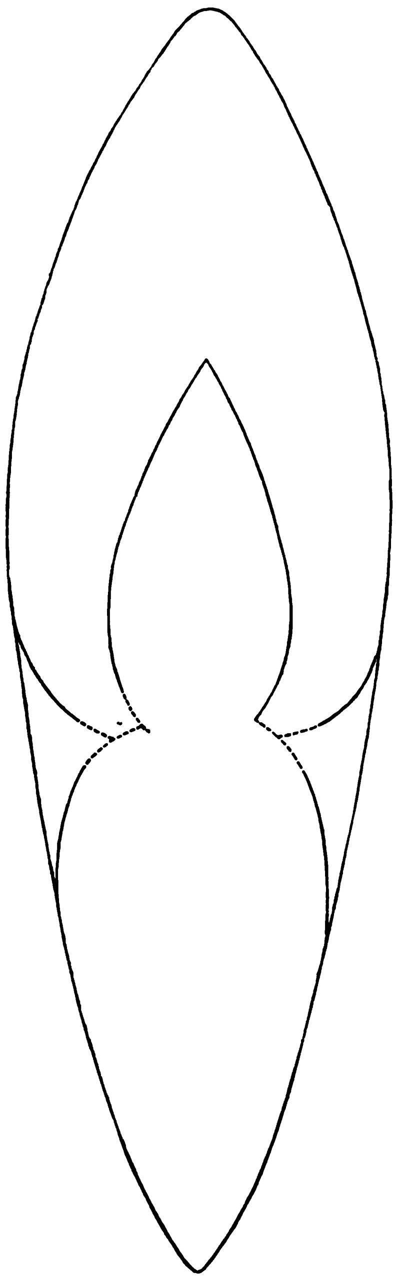
The genus is perhaps related to certain neocomian forms, such as *Ammonites Gevrilianus* d'Orbigny, which have sometimes been regarded as related to *Oxynotoceras*. It is also related to *Ammonites Cleon* d'Orbigny of the Gault, and also to the already mentioned *Sphenodiscus Requieni* of the Turonian.

Its closest ally is probably the neocomian genus *Leopoldia* Baumberger, a genus related to *Hoplites*, and distinguished from *Namadoceras* by the bluntness of its keel, its frequently ornamented shell, and the less pronounced splitting up of the external saddle.

At any rate there is no doubt as to the propriety of including *Namadoceras* amongst the Placenticeratidæ, or "Placenticeratinæ," if the group be regarded as a sub-family of the Hoplitidæ.

NAMADOCERAS SCINDIÆ nov. spec. Pl. 16.

Description.—Smooth shell with deeply frilled sutures, the external half of the complex external saddle greatly ramified, and subdivided, on its inner side, by a marginal lobe so deep as to isolate an almost independent subsidiary saddle; inner half of the external saddle broad, and less deeply ramified, separated by a large complex first lateral lobe from the large first lateral saddle which has a tendency to become bifid; the second lateral lobe and saddle smaller and less complex, followed by a well marked lobe and a low auxiliary saddle beyond which the auxiliary series extends down the umbilical funnel in a serrated line the inflections of which are not distinctly individualised.



Section of *Namadoceras Scindiæ.*

Dimensions.—The solitary fragment is entirely chambered up to its largest radius of 92 millimetres. The species must grow therefore to a very large size. The ratio between the height of a whorl and the corresponding radius is about 5 to 9. The greatest thickness situated at a little less than one-third of the radius from the centre is 56 millimetres at a corresponding radius of about 90 millimetres.

I have dedicated this remarkable ammonite to His

Highness the Maharajah Aleejah Bahadur Scindia in whose dominions the Bagh beds are extensively developed in a series of most interesting exposures.

Locality and geological horizon.—The solitary specimen was discovered by Mr. P. N. Bose in the nodular limestone at Mongra in Chota Udaipur.

NAMADOCERAS BOSEI nov. spec. Pl. 17.

Description.—Shell with slightly developed straight radial folds, especially distinct towards the umbilicus, becoming gradually effaced towards the attenuated, very sharp marginal keel; sutural line moderately frilled, the outer half of the complex external saddle being the only portion deeply ramified; first lateral saddle large and broad, followed by second lateral lobe and saddle, first auxiliary lobe and saddle, and second auxiliary lobe, of gradually decreasing size, beyond which the suture is concealed by the matrix filling the umbilical funnel. All the inflections are somewhat uniform in outline, the saddles tending to a bifid, and the lobes to a trifid disposition.

Dimensions.—The greatest radius of the entirely chambered fragment must have been about 80 millimetres indicating, as in the case of the previous species, an ammonite of large dimensions. The greatest thickness situated at a little over one-quarter the radius from the centre is about 30 millimetres at a radius of 65 millimetres, or $\frac{6}{13}$ of the corresponding radius. The state of preservation of the fragment does not allow an exact measurement of the rate of involution.

Comparison with the previous species.—The shell is somewhat more compressed than that described as *Namadoceras Scindiæ*, but with only one specimen of each species it is not possible to say how far this may be merely an individual accident. The radial folds and the pinched tapering shape of the section towards the keel in *Namadoceras Bosei* are conspicuous distinctions. The sutural line is quite different. It is less minutely frilled and the development of the larger inflections is more pronounced towards the umbilicus and less so towards the external margin in *Namadoceras Bosei* than in *Namadoceras Scindiæ*.

There is no marked tendency towards the individualisation of a median adventitious saddle in the complex external saddle, such as is observed in *Namadoceras Scindiæ*, though this inflection is represented

in a rudimentary manner by a small marginal saddle deeply situated in the adventitious lobe that separates the two masses of the compound external saddle.

Locality and geological horizon.—There is only one specimen which was discovered at the same locality and at the same horizon as the one fragment of the previously described species. The simultaneous occurrence of two completely distinct forms of such a remarkable generic type is a most interesting circumstance.

I have dedicated this second species to its discoverer, my colleague Mr. P. N. Bose.

LIST OF ILLUSTRATIONS.

PLATE 14. Fig. 1.—*Placenticeras Mintoi*, specimen with body whorl complete. Kanori, 2 miles north of Dehri, by the Uri. Nodular limestone.

Fig. 2.—Suture of a full-grown specimen from Murasa near Naupur. Nodular limestone. (The differences between the two consecutive sutures are principally due to the interference from the knobs.)

Fig. 3.—Suture of an immature specimen from the same locality as the one represented in fig. 1, but probably from the Deola and Chirákhán marl.

PLATE 15. Figs. 1, 1*a*.—*Placenticeras Mintoi*, Murasa near Naupur. Nodular limestone.

Fig. 2.—Section of whorl drawn from the same specimen as Pl. 14, fig. 2.

Fig. 3.—Section of a specimen from the nodular limestone. Exact locality unknown.

Fig. 4.—Section of whorl of a specimen from the nodular limestone. Exact locality unknown.

PLATE 16. Fig. 1.—*Namadoceras Scindiæ*. Mongra in Chota Udaipur. Nodular limestone.

Fig. 2.—Suture of the same specimen.

PLATE 17. Fig. 1. *Namadoceras Bosei*. Same locality and horizon as the species represented on the previous plate.

Fig. 2.—Section of whorl of same specimen.

Fig. 3.—Suture of same specimen.

Figure in text, page 123. Section of *Namadoceras Scindiæ*.

All the figures are drawn in natural size.

MISCELLANEOUS NOTES.

A Bituminous Limestone from the Vindhyan Series, Jodhpur State.

A SAMPLE of rock received from the State Engineer, Jodhpur State, Rájputána, and described as having a smell of kerosine oil, consists of several pieces of a dark hair-brown limestone. In some cases the grain is fairly fine (19·167); but in others the rock is very coarsely crystalline (19·168), the cleavage faces being so markedly curved that in one case, where a curved cleavage face two inches across was obtained, the curvature corresponded to that of a circle about 4 inches in diameter. The accompanying woodcut shows a corner where three of these curved cleavage faces, corresponding to those of the unit rhombohedron, meet.

Curved cleavage.

On inspecting the hand-specimen each of the curved cleavage faces is seen to be composed of a number of much smaller facets arranged so as to make small angles with one another. This, of course, accounts to a certain extent for the curvature, but not entirely, for each of these smaller cleavage facets is seen by the aid of a lens to be itself curved. The microscope also shows that although many of the cleavages are composite and owe their curvature to a stepped or *en échelon* arrangement of smaller cleavage cracks, yet many of the curved cleavages are bold and distinct and undoubtedly quite simple. As the large plates of calcite show no signs of strain phenomena in the shape of undulatory extinction or lamellar twinning, the curved cleavage cannot be ascribed to strain; and the only reason that can be advanced to account for the departure of the cleavage of this calcite from that of normal calcite is that possibly the included bituminous matter, to be referred to below, has some effect on the disposition of the calcite molecules.

Curved faces of *crystallization*, usually made up of sub-individuals, are of common occurrence with the allied minerals dolomite and chalybite;

but I am not aware that curved *cleavage* faces have been recorded for any of the minerals of this group, except possibly in the case of obviously strained individuals seen in microscope sections.

The specific gravities of a piece of the finer-grained and of the more coarsely crystalline rock were found to be 2·71 and 2·68 respectively.

Bituminous character.

The rock has a strong fetid or bituminous smell which is stronger on fresh fractures than on old. On dissolving a portion of the rock in dilute hydrochloric acid a brown scum is formed. This is taken up by ether, which then burns with a smoky flame. The rock also gives a slight reaction for sulphur.

Under the microscope the rock shows pale yellowish plates of calcite ophitically enclosing abundant little patches of what seems also to be calcite in different optic orientation to the enclosing plates.

Traversing the yellowish calcite are veinlets of quite clear and colourless calcite. The way in which the bituminous matter occurs is not apparent in the microscope sections, but it may either be uniformly distributed through the yellowish calcite, thus accounting for the colour of the latter, or, less probably, associated with the above-mentioned little patches of calcite (?) enclosed in the larger calcite individuals.

The rock was found near Bilara, and the exact locality is given as "two miles off from Pichak village on the way to Kharya and Udalyawas and about 100 yards north of bank No. II of Jeswant Sagar Tank." This is at lat. 26° 12′ and long. 73° 46′, in Jodhpur State, and is on the Vindhyan formation.

Hence we see that this rock is to be regarded as a bituminous limestone of Vindhyan age.

[L. L. FERMOR.]

Wavellite from the Singhbhum district, Bengal.

Amongst some specimens received from M. R. Ry. Srinivasa Rao, B.A., in 1906, was one (K. 4) showing numerous radiate tufts forming incrustations on, and filling cracks in, a dark grey flint-like quartzite which under the microscope is seen to be composed of a very fine-grained quartz aggregate. The radiate tufts are 0·5 to 1·5 cm. in diameter and of a pale greenish white colour. The mineral suggests wavellite in its general appearance; and that it is this mineral is shown by the fact that it reacts for phosphorus, aluminium, and water. The specific gravity of a small piece was found by means of Sonstadt's solution to be 2·345; this is a trifle higher than the value given by Dana, 2·316 to 2·337. Wavellite has apparently not been previously recorded from India.

The specimen was collected at Gobindpur—lat. 22°37′; long. 85° 36′—about half-way between Chakárdharpur and Sonua station, Bengal-Nagpur Railway, the district being Singhbhum, Bengal.

[L. L. FERMOR.]

Corundum from the Singhbhum district, Bengal.

Amongst the specimens received from M. R. Ry. Srinivasa Rao were several pieces (19·299 to 19·302) of heavy, light greyish and brownish rocks from Lopso Hill, Singhbhum; Lopso Hill is situated about 11 miles North-East of Chakárdharpur station, Bengal-Nagpur Railway (lat. 22°47′: long. 85° 47′). The specific gravity of the rocks ranges from 3·57 to 3·67. The hardness of the specimens indicates at once the presence in the rock of corundum, and the microscope shows that these rocks are granular crystalline aggregates of corundum, containing a certain amount of tremolite, which in some places is aggregated into tufts conspicuous in the hand-specimen. This is a new locality for corundum-bearing rocks in India; Mr. Hallowes who has visited Lopso Hill says that he was only able to find pebbles of these rocks and not to find them *in situ*.

[L. L. FERMOR.]

Apatite-magnetite-rock from the Singhbhum district, Bengal.

Amongst some samples of iron-ores from two villages given as Moosalbali and Pathorghora[1] in Prince Mahomed Bukhtiyar Shah's Dhálbhum Estate, Singhbhum district, Bengal, were several specimens of an interesting apatite-magnetite-rock. The apatite occurs as flecks and spots, sometimes up to ½ inch in diameter, and of a creamy colour, often tinged brown by iron oxide, in what would otherwise be called magnetite-rock. There is one patch, composed almost entirely of apatite, that is 2½ inches long by 1½ broad. The mineral gives all the test of apatite, and is seen under the microscope to have been formed later than the magnetite, which is idiomorphic with respect to the apatite. In many places the interstices of the magnetite are occupied by a golden-coloured micaceous mineral in the place of the apatite, with which it is also sometimes associated. A little quartz occurs in one place and is idiomorphic with respect to the apatite.

In the absence of any information as to the mode of occurrence of this rock or ore, it is difficult to put forward any theory as to its origin.

If this rock occur in any quantity, it might be of considerable value, on account of the considerable percentage of phosphorus it must contain, in the manufacture of basic steel.

[L. L. FERMOR.]

[1] Probably the same as Mosaboni (lat. 22° 31′; long. 80° 30′) and Patholgora (lat. 22° 32′; long. 86° 29′) shown on Standard Sheet No. 186 of the Bengal Survey (Reg. No. 786 S.—05).

Note on the Occurrence of Orpiment on the Shankalpa Glacier, Kumaon.

That orpiment occurs in some locality near Munsyari (80° 18'; 30° 7')[1] has been already pointed out in these *Records* (Vol. II, page 88), but the precise position was apparently unknown.

In September 1906, when visiting the Shankalpa glacier (80° 24; 30 19) we found upon the surface-moraine of the glacier, and about one mile from the ice-cave, scattered fragments of orpiment-bearing rock, showing upon the freshly fractured surfaces minute specks of realgar. The ore covers only a very limited portion of the surface-moraine, and appears to be scattered upon it in the form of an ellipse perhaps ¼ mile in length, and lying close to the north-west side of the valley about one mile from the ice-cave. Outside the margin of this ellipse we found no ore.

It seems probable that the ore has not been carried very far from its home by the flow of the glacier-ice, for if it had been brought down in the same manner as the surface-moraine of the glacier, we should expect to find it distributed throughout the latter and not confined to one particular place. Possibly it may have been carried down by an avalanche from the hill-side. The absence of realgar on the weathered surface of the specimens may possibly indicate that the rock has been exposed to the air for a considerable time; this however is doubtful.[2]

We were unable to discover the source of the fragments both owing to the short time at our disposal and being hampered by fresh falls of snow on slopes ordinarily difficult on account of their great steepness.

The orpiment occurs filling in irregular veins and cracks in a bluish-grey siliceous rock, and is found in foliated masses of a lemon-yellow colour. No crystal faces can be determined although the cleavage is especially well-marked. A specimen of the pure mineral was found to have a specific gravity of 3·45.

Realgar in small granules of the usual red colour is of rare occurrence and is seen only on the freshly fractured surface.

An average sample of about 2,000 gms. of the mineral and gangue was powdered for chemical examination. A determination made by Mr. Brown on material from this shows that the rock contains 23·11 per cent. of arsenic.

[G. DEP. COTTER AND J. COGGIN BROWN.]

[1] See also: Mallet, Manual of the Geology of India, Part IV, page 12, and Atkinson, Economic Mineralogy of the Hill Districts of the North-West Provinces of India, page 31.

[2] Dana, System of Mineralogy, page 34. "Realgar changes to orpiment and arsenolite on exposure to light."

Note on the Tatkan area : blocks 21—26-N, Yenangyaung.

These blocks have been regarded as of Irrawadi sandstone age by Grimes (*Mem. G. S. I.*, XXVIII, p. 60); but the presence of large exposures of clay beds have caused subsequent investigators of these blocks to regard them as possibly Yenangyaungian.

I examined these blocks in April 1907, with the object of determining (1) the age of the clay exposures, and (2) the structure of the strata, whether anticlinal or otherwise.

The clay beds appear to me to be of Irrawadi sandstone age for the following reasons:—

(1) The sandstones exposed in this area are typical Irrawadi sandstones, showing everywhere current-bedding, and containing fossil wood, and they are interstratified with numerous pebble beds (see *Mem. G. S. I.*, XXVIII, p. 70).

(2) The so-called clay beds are, I think, merely large clay pockets in the sandstones, and are of contemporaneous age. Many sections in the stream beds, which I examined, supported this view; thus in the Ngamwe Chaung, a large clay pocket is exposed showing sandstones enclosing it. The clay of these pockets is of an exactly similar type to those of the exposures in the Kyubyu and Thitnyodaw Chaungs, blocks 24 and 26-N, Yenangyaung, where the sandstones apparently overlie the clays with local unconformity, because, as I think, the sections are not deep enough to show the lower boundaries of the pockets.

(3) Although gypsum has been reported from these blocks, it appears to be very scarce. In the Yenangyat area gypsum is also found in the Irrawadi series in small quantity.

(4) The clay of these exposures differs from Yenangyaungian clays in that it is jointed, not laminated or bedded, and it may well be a fresh-water deposit.

(5) The well-sections of the two wells drilled in this area show a series of soft sandstones and clays with bands of siliceous pebbles; these occurrences are suggestive of an Irrawadi sandstone age.

Structure.—After a careful examination of the structure, I came to the conclusion that the strata are slightly undulatory and practically horizontal. The exact dip is often unobtainable owing to the prevalence of current-bedding and the softness of the sandstones.

If the above views be correct, the prospects of oil in these blocks are almost hopeless.

[G. DEP. COTTER.]

Fossils from the Miocene of Burma.

A collection of fossils has been received from Mr. L. G. Boyd, of which 12 species come from Singu, 23 species from the southern continuation of the Gwegyo anticline, now known as the Payagyigon-Ngashandaung oil-field, 8 from Padaung near Prome, 5 from the Kabat anticline, 2 from Taungtha Hill, and 3 from the hills near Kwatalin 20 miles south of Taungtha. The following is a list of the species from the different localities :—

Singu.—

Pecten kokenianus Noetl.
Arca yawensis Noetl.
Tellina grimesi Noetl.
„ *indifferens* Noetl.
„ *protocandida ?* Noetl.
Lithodomus sp.
Vermetus sp.
Oniscidia minbuensis ? Noetl.
Voluta ringens Noetl.
Conus malaccanus ? Hwass.
Cassis d'archiaci Noetl.
Balanus tintinnabulum Linné.

Payagyigon-Ngashandaung field.—Of the 27 species from this area, 15 come from a locality one mile west-south-west of Payagyigon village, and it seems probable that they represent the zone of *Paracyathus cæruleus* Noetling. The following is a list :—

Tellina indifferens Noetl.
Scalaria sp.
Terebra ? sp.
Mitra sp.
Rimella crispata Sow.
Cancellaria davidsoni d'Arch. and Haime.
„ *martiniana* Noetl.
Voluta dentata Sow.
Oliva rufula Duclos.
Cypræa granti d'Arch. and Haime.
Drillia yenanensis Noetl.
„ *protointerrupta* Noetl.
Surcula feddeni Noetl.
Pleurotoma cf. woodwardi Martin.
„ *cf. tigrina* Martin.

Other species from unstated localities in this field are as follows :—

Temnopleurus sp.
Tellina protostriatula ? Noetl.
„ *grimesi* Noetl.
Ficula theobaldi Noetl.
Calliostoma sp.
Siliquaria sp.
Drillia protocincta ? Noetl.
Basilissa lorioliana Noetl.
Oniscidia minbuensis ? Noetl.
Ceratotrochus alcocki Noetl.
Nautilus sp.
Balanus tintinnabulum Linné.

It is interesting to note that the fossils from this field have been subjected to considerable pressure, many of them having been squeezed flat. For this reason also they are often too badly preserved for accurate determination.

Padaung (*Prome*).—The following fossils were obtained from a reef in the Irrawadi river :—

Tapes protolirata Noetl.
Dione protolilacina Noetl.
Solarium sp.
Meiocardia sp.
Cucullæa protoconcamerata Noetl.
Arca sp.
Turrilla acuticarinata Dunker (some specimens showing forms which are intermediate between this species and *T. lydekkeri* Noetl.).
Conus malaccanus Hwass.

Kabat anticline.—

Nerita ? sp.
Conus malaccanus Hwass.
Pyrula bucephala Lam.
Conus literatus Linné,
Voluta dentata Sow.

Taungtha Hill.—

Spine of *Myliobates ?* Noetl.
Balanus tintinnabulum Linné,

Hills near Kwatalin, 21 miles south of Taungtha.—

Vicarya callosa Martin.
Cytherea erycina Favanne.
Scutella ? sp.

[G. DEP. COTTER.]

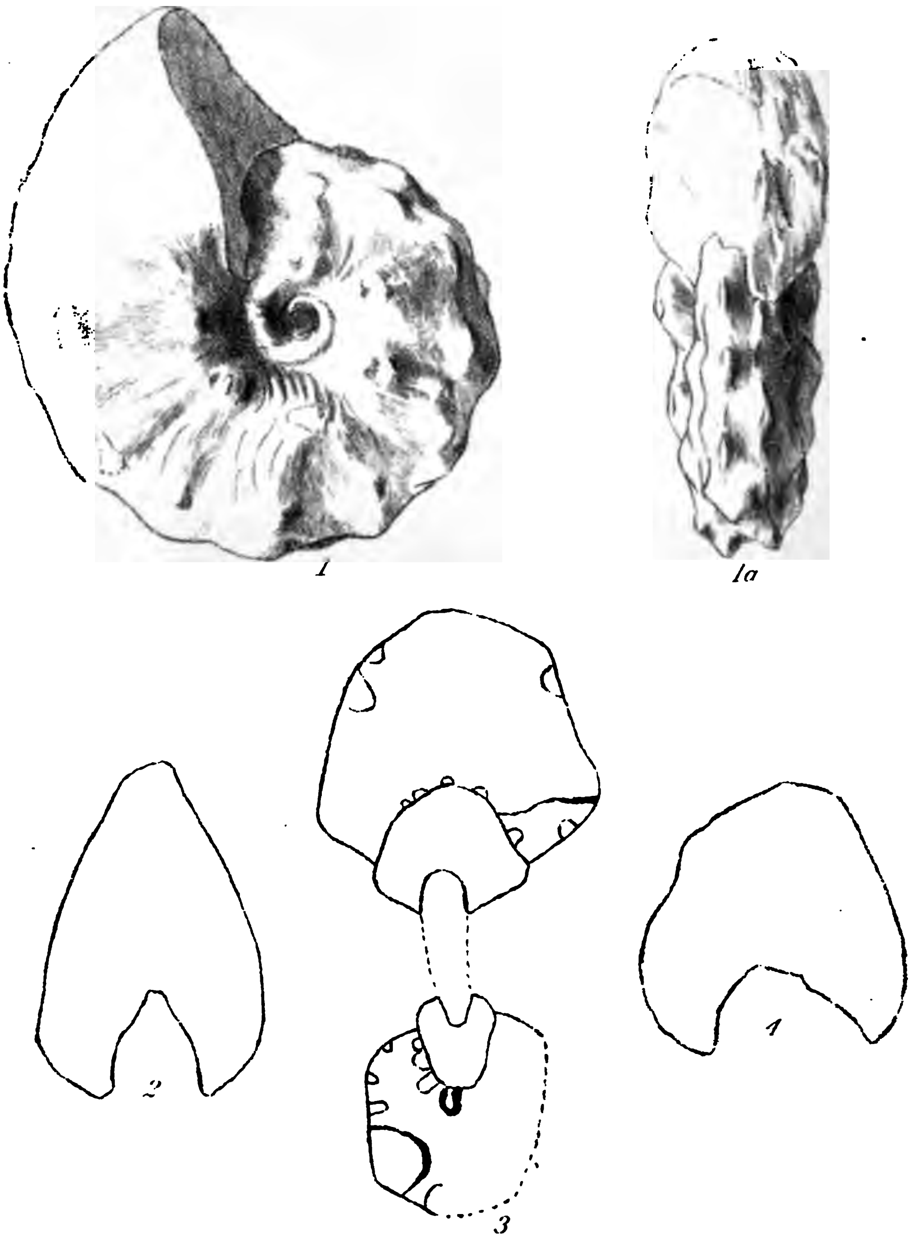
Some Triassic Ammonites from Baluchistan.

While looking through a collection of fossils made in Baluchistan by Kishen Singh, late Sub-Assistant, a number of ammonites embedded in a black shale were noticed. Their general appearance suggested that they were probably Triassic in age. The label with the specimens reads: "In a concretion in black shales No. 5, about 2 miles south-west of Babazai." Reference to the Museum register shows that these fossils come from the Brewery beds which are said to belong to the Dunghan group. I have not been able to find the village mentioned by Kishen Singh on any map, but reference to his maps makes it certain that these specimens come from the Brewery hill, west of Quetta, as this is the only locality where the strata No. 5 are marked. The ammonites, which are generally small and stunted forms, are crowded in a black calcareous shale. The interior of each ammonite has been replaced by calcite. The individual specimens are difficult to extract. Of those that can be got out are some very involute ammonites with a shape which recalls *Rhacophyllites Vredenburgi* described by Diener from the Triassic shales near Pishin. The difference lies in the umbilicus which is obsolete in the present specimen. The suture line being of the Phylloceratid type, this fossil must be called *Phylloceras*. At least six specimens of this fossil occur.

Some small, rather globose involute forms ornamented with smooth ribs which are not prominent show great resemblances to *Ptychites*.

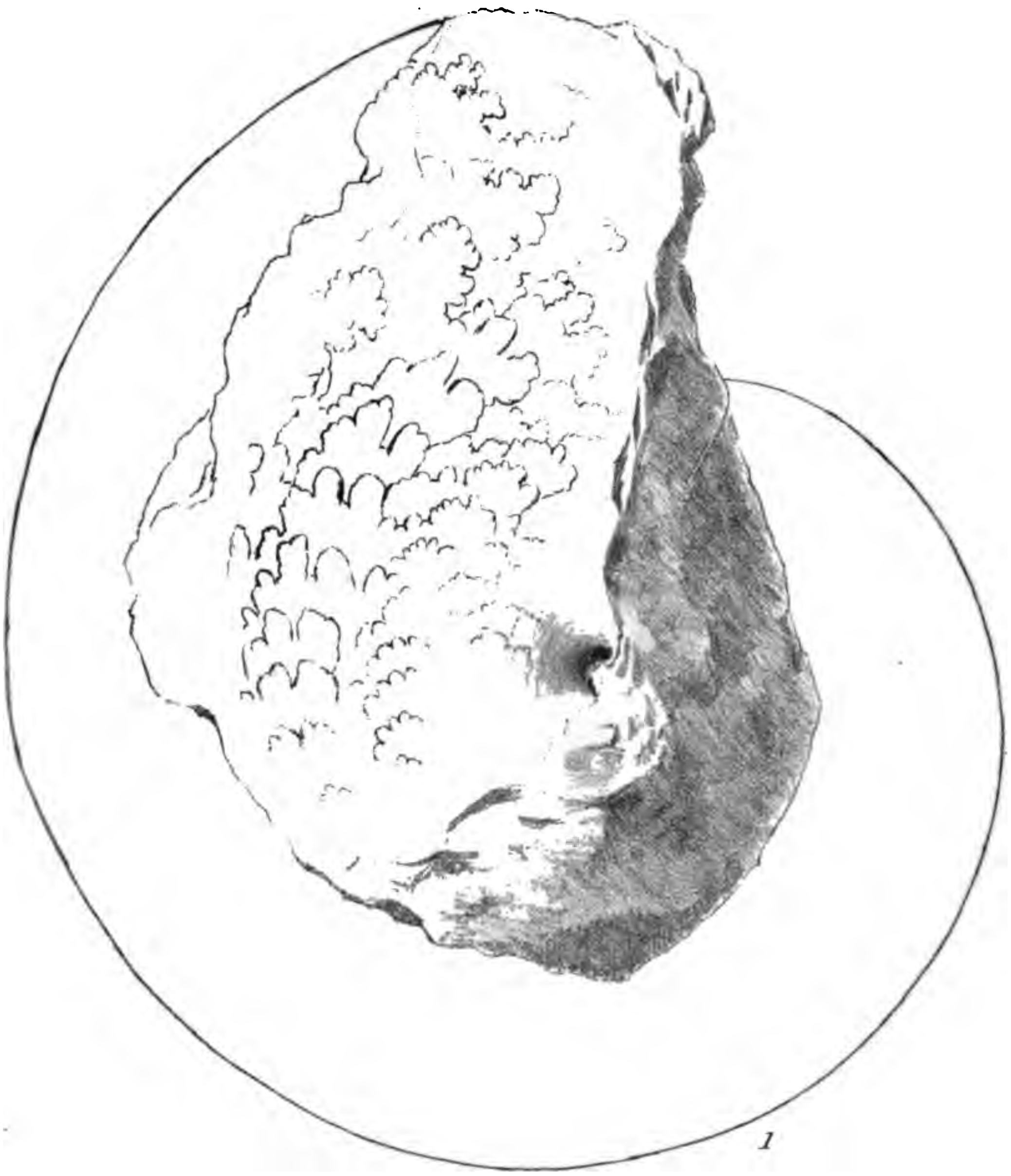
A fragment of an involute ammonite ornamented by fine longitudinal ribs seems to belong to the genus *Cladiscites*. The sutures have not been seen. The other ammonites have not been identified, but they seem to be Triassic, at any rate in appearance. The presence of this probably upper Triassic deposit in the Brewery beds is probably to be accounted for by faulting, the region round Quetta being a very disturbed one.

[G. H. TIPPER.]



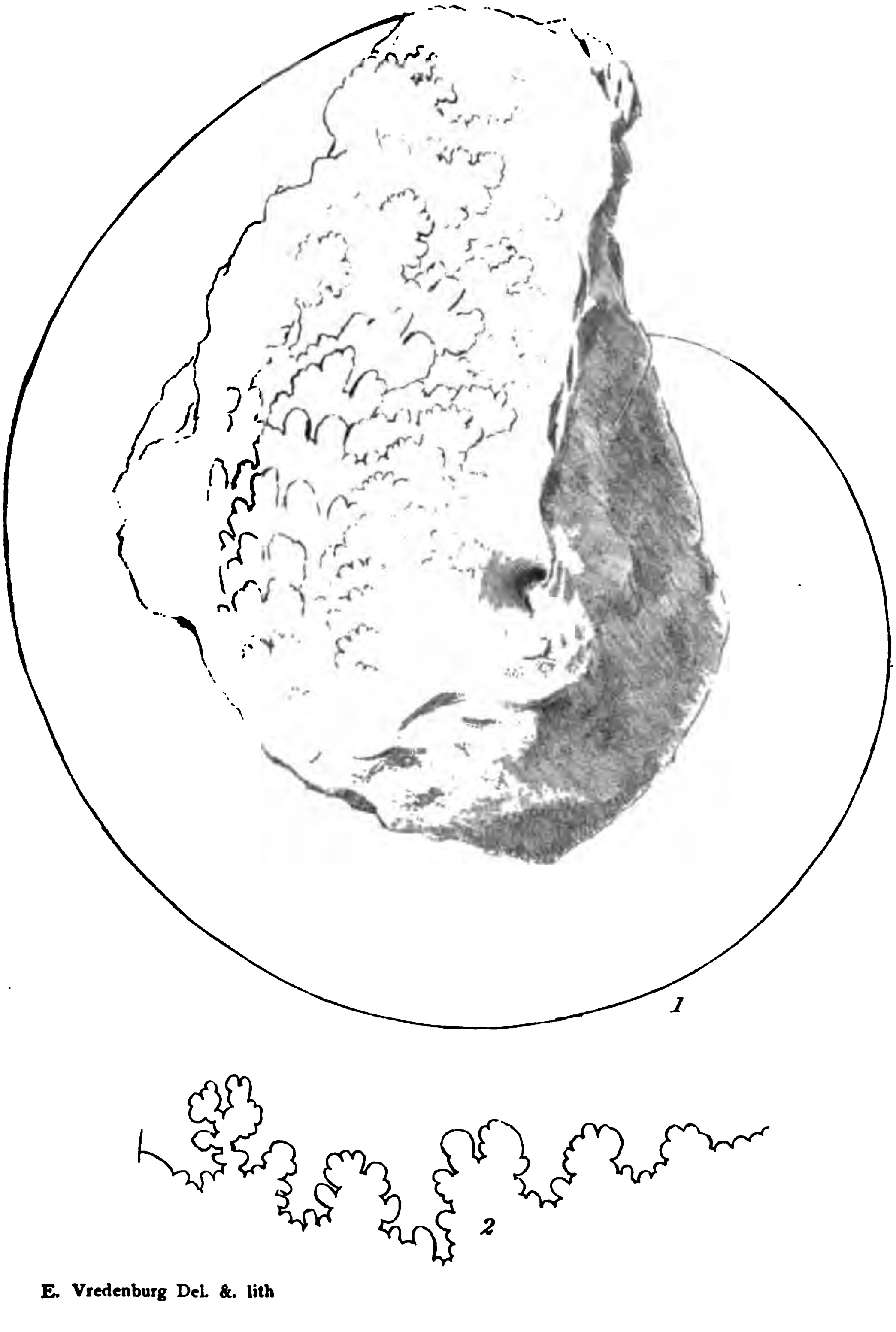
E. Vredenburg Del. &. lith.

Placenticeras Mintoi, nov. spec.



E. Vredenburg Del. &. lith

Namadoceras Scindiæ, nov. spec.



E. Vredenburg Del. &. lith

Namadoceras Scindiæ, nov. spec.